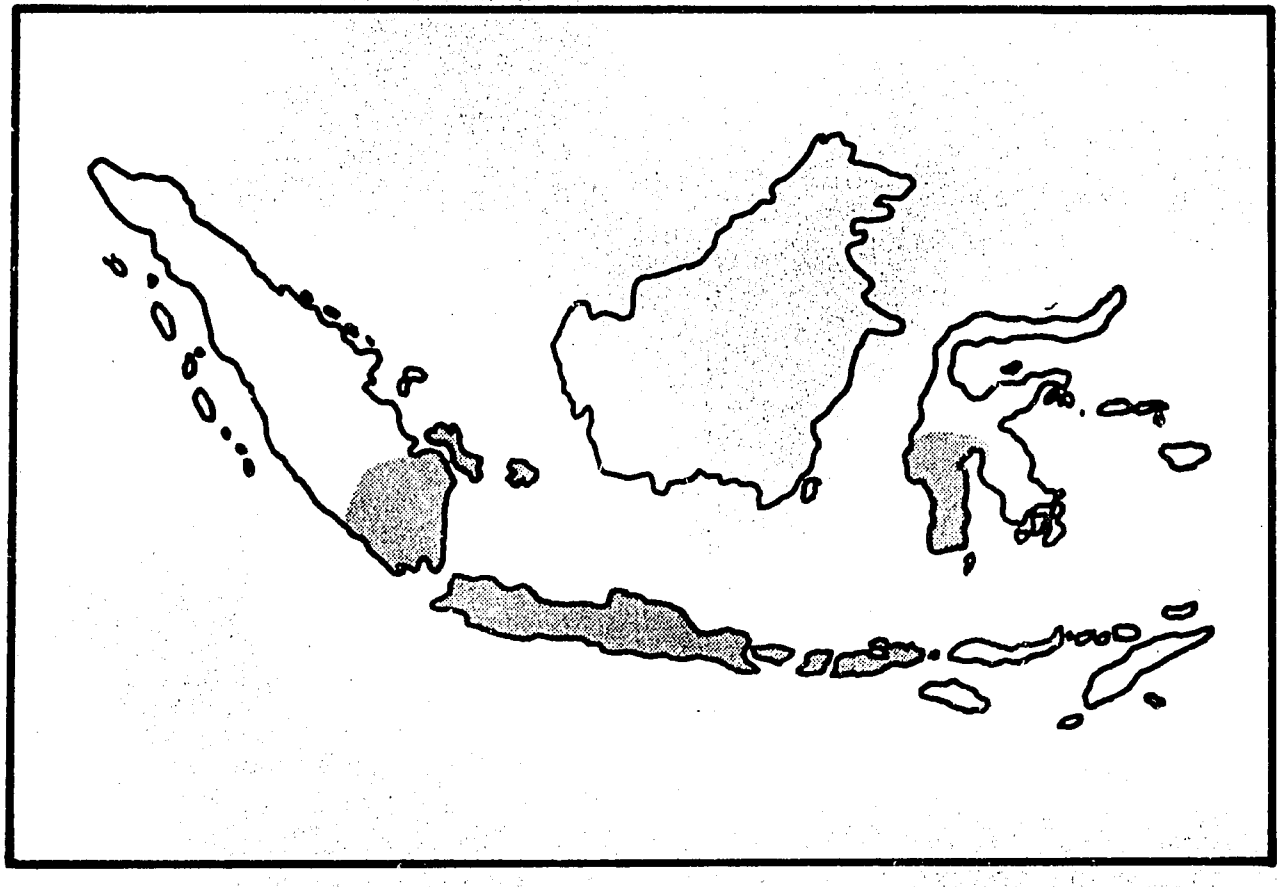
PN-AAS-343

PROPOSED AGROCLIMATIC ASSESSMENT MODELS FOR SECONDARY FOOD CROPS IN INDONESIA



FINAL REPORT

SUTRISNO

NOVEMBER 1982

PN-AAS-343

PROPOSED AGROCLIMATIC ASSESSMENT MODELS FOR SECONDARY FOOD CROPS IN INDONESIA

Final Report

to

Departemen Perhubungan Badan Meteorologi dan Geofisika
Jakarta, Indonesia

by

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for

U.S. Agency for International Development
Agriculture Development Office
Jakarta, Indonesia

Agency for International Development[2/]
Office of U.S. Foreign Disaster Assistance
and
Asia Bureau/Technical Resources
Washington, D.C.

November 1982

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2/ This project was sponsored by AID and conducted by the U.S. National Oceanic and Atmospheric Administration, Environmental Data and Information Service, Assessment and Information Services Center-Models Branch Columbia, Missouri and University of Missouri-Columbia, Atmospheric Science Department in Columbia, Missouri under NOAA/AID PASA IND-0000-P-CC-1025-02 and NOAA-UMC Cooperative Agreement Number NA82AA-H-00024.

FORWARD

This report by Mr. Sutrisno, Agricultural Meteorologist, Meteorological and Geophysical Service (BMG), describes agroclimatic assessment models developed for rainfed agriculture in Indonesia. These models can be used to implement a reliable, timely, yet inexpensive weather-based information system in Indonesia. Weather analysis and climatic impact assessments can help decision makers including managers, agronomists, economists, statisticians, agrometeorologists, and extension officials interpret and anticipate weather impacts on the agricultural sector. Specifically, the system will continuously monitor and assess the impact of weather (drought, flooding, high winds, heat stress, etc.) on agriculture. Early warning of potential crop failure due to drought can be provided 30-60 days before crop harvest. This may represent a 3-6 month lead-time to develop strategies for improving food security. Agroclimatic/crop condition assessments can be provided during the crop growing season. These represent additional tools to complement and supplement other information sources used by statisticians to forecast crop production. Soil moisture estimates can be provided to the extension service. These agroclimatic models also offer potential long-term economic benefits related to agricultural planning and rural development, e.g., minimizing climate risk in land and water resource management.

Java, Southeast Sumatra, Southwest Sulawesi, Bali, and West Nusa Tenggara were chosen for this pilot study because weather and climate are major factors that help determine potential crop productivity and year-to-year variations in agricultural production levels. Also, this proposed weather assessment system complements ongoing or planned developmental projects involving rainfed agriculture and secondary food crops. The proposed agroclimatic assessment system is ready to be tested and evaluated. After successful testing, the system can be expanded to include other regions in Indonesia.

This work is the result of an intensive six week Orientation Program on Agroclimatic Models and Climate Impact Assessment Technology. The program was conducted in Columbia, Missouri, through the joint efforts of the NOAA/NESDIS Assessment and Information Services Center (AISC) - Models Branch and the Atmospheric Science Department, University of Missouri - Columbia. The project was sponsored by the Agency for International Development, Office of U.S. Foreign Disaster Assistance (AID/OFDA), Washington, D.C., as part of a NOAA/AID effort to transfer agroclimatic assessment technology to Southeast Asia. Individuals in these agencies making contributions to this study include: Dr. Wayne L. Decker, Dr. Andres C. Ravelo, Dr. Atanas V. Todorov, Ken Wherry, Judy Trujillo, Betty Whitmarsh and Jerry Wright of the University of Missouri - Columbia; Dr. Clarence M. Sakamoto, Rita Terry and Susan Conrad, NOAA/NESDIS/AISC-Models Branch, Columbia Missouri; and Alan Hankins, AID/ASIA/TR, Walter C. Tappan, US/AID Mission Jakarta and Paul Krumpe, AID/OFDA.

We were privileged to work with Mr. Sutrisno. He dedicated himself to many extra hours of work in developing this study. Assistance from officials in the Government of Indonesia is also appreciated, in particular, Drs. C. Sutrisno, DG/BMG, and Mr. Sujadi Hardjawinata, Director, Analysis and Planning, BMG.

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*

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CHAPTER I

INTRODUCTION

Indonesia is the world's largest archipelago encompassing nearly 1.9 million square kilometers across an east-west distance of 5,600 km. Agriculture plays a very important role in the national economy even though only about 8 percent of the land is arable. Sixty percent of the working population is engaged in agriculture; agricultural products account for more than half of the national income. Major food crops, in order of importance, include: rice, maize, cassava, sago, sweet potatoes, yams, peanuts, soybeans and beans. However, adverse climate and weather sometimes lead to crop failures and production losses. These in turn affect the national economy and prosperity of the Indonesian population.

The success of cropping practices depends on weather, climate, soil properties and the genetic potential of the crop. These factors also limit potential crop yield. The year-to-year variations in yield are largely determined by climate, particularly when traditional cultural practices are adapted for rainfed crops. The climatic hazards for crops are flooding and drought. Depending on the severity, the effects of flooding are usually location specific. However, severe drought impacts are usually more widespread. Drought can lead to national disaster and in extreme cases starvation, long-range economic dislocations and social disturbances. For example, the severe drought of 1982 in Irian Jaya adversely impacted subsistence agriculture, which led to serious food shortages.

The purpose of this research is to develop the scientific foundation for a Climatic Impact Assessment Program in Indonesia. Assessments are based on agroclimatic models developed from historic, climatic and agricultural data. Assessments primarily focus on potential drought impact as related to short and

long-term economic planning needs. In the short-term, decadal or monthly assessment reports on climatic impact can be used by policy and decision-makers, economic analysts, agricultural forecasters and extension officials to develop strategies to mitigate potential drought impact. These same agroclimatic models can contribute to land and water resource management studies for long-term economic benefits in agricultural planning and rural development. The results of this research can be used in various fields as follows:

1) Early Warning Assessment reports on potential crop failure due to drought or flooding can be used by policy-makers and economic analysts to mitigate potential climatic impact on food security and develop alternative strategies in economic planning. This early warning can represent as much as a 3-6 month lead-time before the occurrence of economic impacts.

2) Crop Condition Assessments can be used by agricultural statisticians and economists to supplement and complement other information sources (e.g., field reports, probability sampling, crop cutting and market analysis) for forecasting crop production. For example, reliable crop condition information can be provided about 30 days before the harvest begins.

3) Weather advisories and crop condition reports can be used by extension officials as one source of information in making recommendations to farmers on planting dates, irrigation scheduling, pest management practices and/or fertilizer application.

4) Agroclimatic tools (plant water stress estimates, crop water requirements and climatic risk analysis) can benefit land and water resource management studies for agricultural planning and rural development.

This report is written to provide background and technical information for those potentially involved with agroclimatic modeling and preparing the assessments. Chapter II provides agroclimatic background information for Indonesia, i.e., the physical environment and agricultural practices. The data bases and methodology are discussed in Chapter III with some analytic results discussed in Chapter IV. Crop modeling results and climatic impact assessment procedures can be found in Chapters V and VI, respectively. Recommendations for program implementation and future work are discussed in Chapter VII. Chapter VIII provides concluding remarks. Substantial data bases are provided in various Appendices and Supplements.

The goal is to provide users in government agencies with assessments based on these models. Although assessments must be thoroughly tested and evaluated under quasi-operational conditions, this proposed climatic impact assessment program has the potential to provide reliable, timely, yet inexpensive information. This information on climatic impact can be used as an additional information source to complement and supplement existing or planned information sources used for economic planning and decision making.

CHAPTER II

AGROCLIMATIC BACKGROUND

1. Physical Environment

The Indonesian archipelago consists of about 13,000 islands of which 992 are inhabited. The five islands of Sumatra, Java, Kalimantan, Sulawesi and Irian Jaya account for 90 percent of the total land area.

The landscape of Indonesia is quite varied with more than 20 mountains scattered among lowlands, valleys, plateaus and swamps. Most of the mountains are covered by tropical forest and many are either active or extinct volcanoes. The topography of the five main islands is briefly summarized below.

Sumatra has an extensive mountain range which parallels the west coast. Elevations of some mountains are in excess of 3,700 m. There are lowlands on both sides of these mountains and large swamps to the southeast. The mountains in Java lie much closer to the southern coast and are not as continuous as those in Sumatra. The mountains in Kalimantan lie along the Malaysian border; the region to the south is a vast lowland with swamps. Sulawesi is extremely mountainous and has few narrow coastal plains. A large high mountain range spans the central region of Irian Jaya. The mountain elevations range up to 5,000 m. Dense tropical forest covers the mountains while the lowlands are either forested or swampland. The elevation of the principal area under investigation is shown in Figure 2.1.

There are numerous rivers in Indonesia, but due to the size and shape of the islands most of the rivers are short with a small to moderate amount of water flow. The flow of water varies essentially from season to season, particularly in Java. In the rainy season these rivers swell and often inundate the low-lying areas, while in the dry season the water level decreases below that necessary for irrigation.

INDONESIAN STUDY AREA
SELECTED PROVINCES
ELEVATION MAP (m)

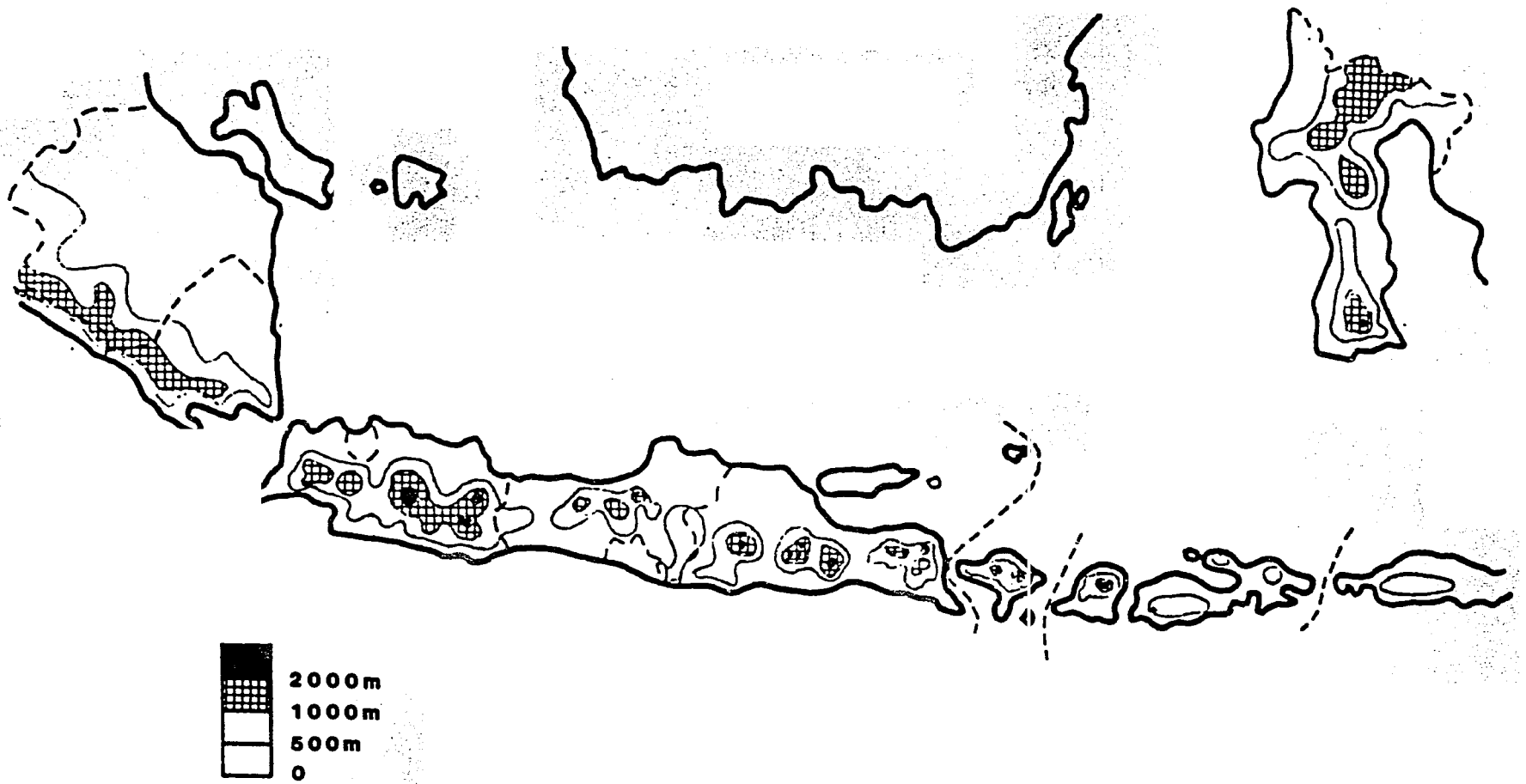


FIGURE 2.1 Elevation Map for Selected Provinces in Indonesia.

2. Administrative Regions and Population

The whole country is divided into 27 provinces (Figure 2.2 and Table 2.1) and each province is further subdivided into residencies, districts and villages.

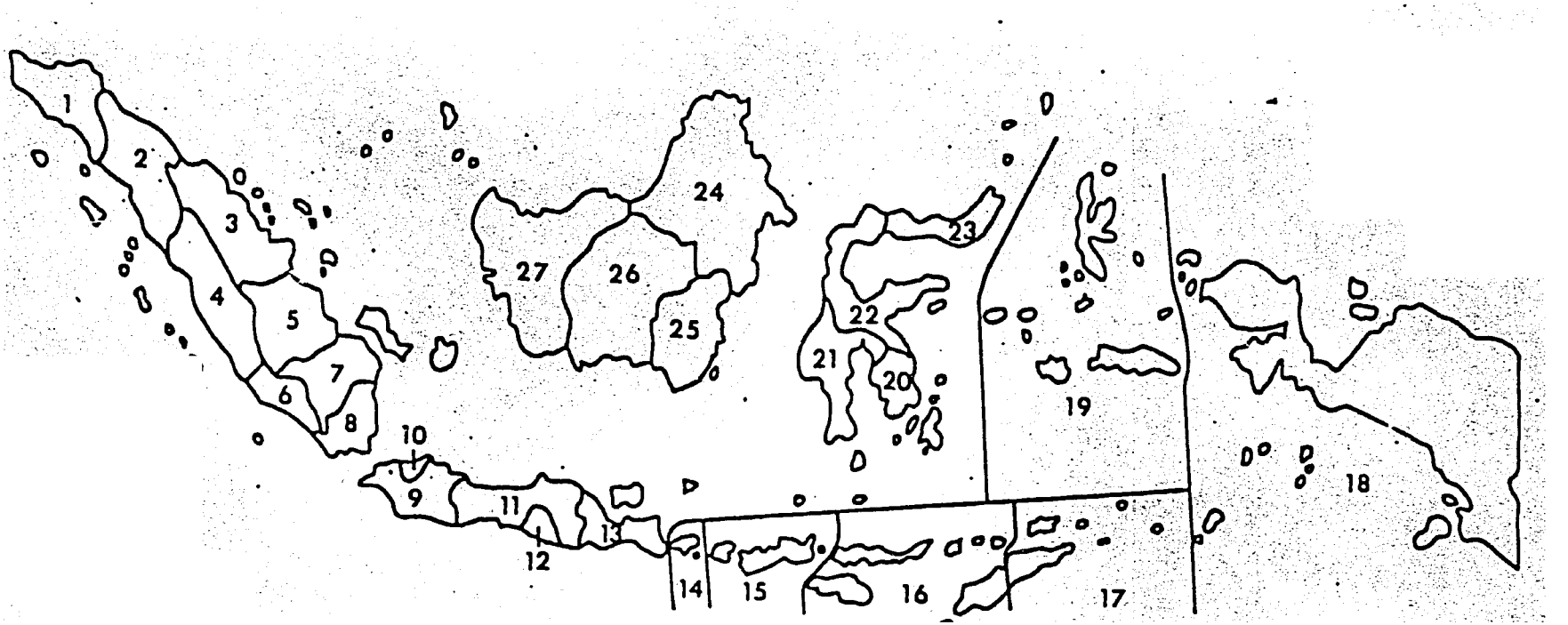
The population of Indonesia is about 150 million. It's distribution however, is very uneven. The population density in Java's provinces is between 593 and 11,023 persons per square kilometer, while Irian Jaya has an average of only 3 persons per square kilometer (Table 2.1). Currently the Indonesian Government has a project (The Transmigration Project) to redistribute the population of the country by resettling people from the densely populated islands to the undeveloped and sparsely populated provinces of Irian Jaya, Sulawesi, Kalimantan and Sumatra.

3. Soils and Natural Vegetation

Indonesian soils vary from place to place due to the large size of the country and the various topographic features, climatic differences, and types of natural vegetation. There are at least ten major soil groups, and numerous subgroups. Organic soils can be found in the lowlands along the coasts of Sumatra, Kalimantan and Irian Jaya. Mineral soils primarily exist at higher elevations. Because of continuous enrichment by volcanic ash and alluvial sediment, the soils in Java and parts of Sumatra, Nusa Tenggara and Sulawesi are more fertile than those on other islands. The water holding capacities of these soils are shown in Table 2.2.

The natural vegetation of Indonesia consists mostly of dense tropical forest in the upland areas, and mangrove and/or swamp vegetation along the coasts. The distribution of forests and non-agricultural land in the study area is shown in Figure 2.3. In the cultivated areas, Pinus sp. are found at higher elevations while Tectona Grandis and bamboo prevail in the lowlands. Grasslands in Sumatra,

INDONESIA PROVINCES AND CROP REPORTING AREAS



1. D.I. ACEH
2. SUMATRA UTARA
3. SUMATRA BARAT
4. RIAU
5. JAMBI
6. BENGKULU
7. SUMATRA SELATIN
8. LAMPUNG
9. KALIMANTAN BARAT
10. KALIMANTAN TENGAH
11. KALIMANTAN TIMUR
12. KALIMANTAN SELATAN
13. SULAWESI SELATAN
14. SULAWESI TENGGARA
15. SULAWESI TENGAH
16. SULAWESI UTARA
17. MALUKU
18. IRIAN JAYA
19. NUSA TENGGARA TIMUR
20. NUSA TENGGARA BARAT
21. BALI
22. JAWA TIMUR
23. D. I. YOGYAKARTA
24. JAWA TENGAH
25. JAWA BARAT
26. D. K. I. JAKARTA

KEY WORDS

UTARA	=	NORTH
SELATIN	=	SOUTH
BARAT	=	WEST
TIMUR	=	EAST
TENGGARA	=	SOUTHEAST
TENGAH	=	MIDDLE

FIGURE 2.2 Provinces and Crop Reporting Areas in Indonesia.

Table 2.1 Area and Population Density of the Provinces and Islands of Indonesia

Province	Area (km^2)	Area % of total area	Population density (persons/km^2)
Daerah Istimewa Aceh	55,392	2.88	47
Sumatra Utara	70,787	3.69	118
Sumatra Barat	49,778	2.59	68
Riau	94,562	4.93	23
Jambi	44,924	2.34	32
Bengkulu	21,168	1.10	36
Lampung	30,307	1.74	139
Sumatra Selatan	103,688	5.40	45
Sumatra total	473,606	24.67	59
D.K.I. Jakarta	590	0.03	11,023
Jawa Barat	46,300	2.41	593
Jawa Tengah	34,206	1.78	742
D.I. Jogyakarta	3,169	0.17	868
Jawa Timur	47,922	2.50	609
Jawa total	132,187	6.89	690
Bali	5,561	0.29	444
Nusa Tenggara Barat	20,177	1.05	135
Nusa Tenggara Timur	47,876	2.49	57
Timor Timur	14,874	0.78	37
Nusa Tenggara total	88,488	4.61	96
Kalimantan Barat	146,760	7.65	17
Kalimantan Tengah	152,600	7.95	6
Kalimantan Selatan	37,660	1.96	55
Kalimantan Timur	202,440	10.55	6
Kalimantan total	539,460	28.11	12
Sulawesi Utara	19,023	0.99	111
Sulawesi Tengah	69,726	3.63	18
Sulawesi Selatan	72,781	3.79	83
Sulawesi Tenggara	27,686	1.44	34
Sulawesi total	189,216	9.85	55
Maluku	74,505	3.88	19
Irian Jaya	421,981	21.99	3
TOTAL INDONESIA	1,919,443	100.00	77

Table 2.2 Basic Agroclimatic Data for Selected Provinces in Indonesia

STATION							Peak sowing and harvesting months and crop water management practice 4)				Months for calculating indices and making assessments				
Name	Type 2)	Reporting frequency 3)	Elevation (m)	Mean Annual rainfall (mm)	Prevailing soil depth (cm)	Capacity of available water in the prevailing soils mm/1m soil	rice	maize	soybean	cassava	rice	maize	soybean	cassava	Months for calculating GMI
Province: Sumatra Selatan															
Palembang	A	d	11	2496	100	100-120	11-3m	4-7r	4-6r	11-7r	11-2	4-7	4-6	11-5	11-2;4-7
Pangkalpinang	A	d	33	2776	100	100-120	11-3r	4-7r	4-6r	11-7r	11-2	4-7	4-6	11-5	11-2;4-7
Tanjungpandan	A	d	44	3256	75	80-100	11-2r	10-1r	3-6r	11-7r	11-2	10-1	3-5	11-5	11-2;4-7
Baturaja	C	m	150		100	100-120	11-3m	4-7r	-	-	11-2	4-7	-	-	11-2;4-7
"	C	m	"		"	"	4-8w	-	-	-	4-7	-	-	-	-
Kasui	C	m	198		100	100-120	11-3m	4-7r	-	-	11-2	4-7	-	-	11-2;4-7
"	C	m	"		"	"	4-8w	-	-	-	-	-	-	-	-
Province: Lampung															
Telukbetung	A	d	10		100	100-120	10-2m	10-1r	4-6r	10-7r	10-1	10-1	4-6	10-4	10-1;3-6
"	A	d	"		"	"	3-7w	-	-	-	3-6	-	-	-	-
Tamanbogo	B	m	20	3068	100	100-120	11-2m	4-7r	4-6r	11-8r	11-2	4-7	4-6	11-5	11-2;4-7
"	B	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Kotabumi	C	m	32	2488	100	100-120	11-2r	11-2r	4-6r	11-7r	11-2	11-2	4-6	11-5	11-2;4-7
Menggala	C	m	20		100	100-120	11-2r	11-2r	4-6r	11-7r	11-2	11-2	4-6	11-5	11-2;4-7
Province: Jakarta															
Kemayoran	A	d	5	2129	100	100-120	11-2w	-	-	-	11-2	-	-	-	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
H. Perdanakusuma	A	d	30	2317	100	100-120	11-2w	-	-	-	11-2	-	-	-	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Province: Jawa Barat															
Serang	A	d	25	1870	100	100	11-3w	4-7m	4-6m	11-7r	11-2	4-7	4-6	11-5	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Bandung	A	d	746	2029	100	100-120	11-3w	4-7m	4-6m	11-7r	11-2	4-7	4-6	11-5	11-2;4-7
"	A	d	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-

Table 2.2 Basic Agroclimatic Data for Selected Provinces in Indonesia (continued)

STATION Name	Type 2)	Reporting frequency 3)	Elevation (m)	Mean Annual rainfall (mm)	Prevailing soil depth (cm)	Capacity of available water in the prevailing soils mm/1m soil	Peak sowing and harvesting months and crop water management practice 4) rice	maize	soybean	cassava	Months for calculating indices and making assessments rice	maize	soybean	cassava	Months for calculating GMI
Province: Jawa Barat (continued)															
Muara	B	m	260	4291	100	100	10-2w	4-7m	4-6m	11-7r	10-1	4-7	4-6	11-5	10-1;3-6
"	B	m	"	"	"	"	3-6w	-	-	-	3-5	-	-	-	-
Cipanas	B	m	1100	3229	100	120	-	-	-	-	-	-	-	-	11-2;4-7
Margahayu	B	m	1250	2337	100	120	-	-	-	-	-	-	-	-	11-2;4-7
Pusakanegara	B	m	7	1969	100	100	11-3w	-	4-6m	11-7r	11-2	-	4-6	11-5	11-2;4-7
"	B	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Kuningan	B	m	545	2092	100	100-120	11-3w	4-7m	4-6m	11-7r	11-2	4-7	4-6	11-5	11-2;4-7
"	B	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Pandeglang	C	m	252	2437	100	100	10-2w	4-7m	4-6m	11-7r	10-1	4-7	4-6	11-5	10-1;3-6
"	C	m	"	"	"	"	3-7w	-	-	-	3-6	-	-	-	-
Malingping	C	m	77	3212	100	100	11-3w	4-7m	4-6m	11-8r	11-2	4-7	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Agrabinta	C	m	200		100	100	11-3m	4-7m	-	11-7r	11-2	4-7	-	11-5	11-2;4-7
"	C	m	"		"	"	4-8w	-	-	-	4-7	-	-	-	-
Tasikmalaya	C	m	350	3258	100	80	11-3w	4-7m	4-6m	11-7r	11-2	4-7	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Province: Jawa Tengah															
Cilacap	A	d	6	3512	100	100	11-2w	4-7m	4-6m	-	11-2	4-6	4-6	-	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Tegal	A	d	1	1798	100	100	11-2m	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Semarang/Akhmadyani	A	d	3		100	100	11-2w	4-7m	4-6m	11-8r	11-2	4-6	4-6	11-5	11-2;4-7
"	A	d	"		"	"	4-7w	-	-	-	4-6	-	-	-	-

Table 2.2 Basic Agroclimatic Data for Selected Provinces in Indonesia (continued)

STATION Name	Type 2)	Reporting frequency 3)	Elevation (m)	Mean Annual rainfall (mm)	Prevailing soil depth (cm)	Capacity of available water in the prevailing soil mm/1m soil	Peak sowing and harvesting months and crop water management practice 4) rice	maize	soybean	cassava	Months for calculating indices and making assessments rice	maize	soybean	cassava	Months for calculating GMI
Province: Jawa Tengah (continued)															
Jakenan	B	m	7	1470	100	100	11-3m	11-2m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	B	m	"	"	"	"	4-7w	4-7m	-	-	4-6	-	-	-	-
Bongos	C	m	495		100	80-100	11-3m	-	-	-	11-2	-	-	-	11-2;4-7
"	C	m	"		"	"	4-8w	-	-	-	4-7	-	-	-	-
Pekalongan	C	m	3	2453	100	100	11-3m	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Waleri	C	m	10	2414	100	100	11-2m	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Magelang	C	m	380		100	100	11-3w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	C	m	"		"	"	4-7w	-	-	-	4-6	-	-	-	-
Province: Yogyakarta															
Adisucipto	A	d	115	1839	100	90	11-3w	4-7m	3-6m	11-7r	11-2	4-6	3-5	11-5	11-2;4-7
Wuryantoro	C	m	180	2095	75	90	11-3r	11-3r	3-6r	11-7r	11-2	11-2	3-5	11-5	11-2;4-7
"	C	m	"	"	"	"	-	4-7r	-	-	-	4-6	-	-	-
Province: Jawa Timur															
Madiun/Iswahyudi	A	d	105	1964	100	100	11-2w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Surabaya/Tanjung Perak	A	d	3	1533	100	100	11-2w	4-7m	3-5m	11-7r	11-2	4-6	3-5	11-5	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Kalianget	A	d	3	1435	75	90	11-3m	11-2r	4-6m	11-7r	11-2	11-2	4-6	11-5	11-2;4-7
"	A	d	"	"	"	"	-	3-6m	-	-	-	3-5	-	-	-

Table 2.2 Basic Agroclimatic Data for Selected Provinces in Indonesia (continued)

STATION							Peak sowing and harvesting months and crop water management practice 4)				Months for calculating indices and making assessments				
Name	Type 2)	Reporting frequency 3)	Elevation (m)	Mean Annual rainfall (mm)	Prevailing soil depth (cm)	Capacity of available water in the prevailing soil mm/1m soil	rice	maize	soybean	cassava	rice	maize	soybean	cassava	Months for calculating GMI
							Province: Jawa Timur (continued)								
Banyuwangi	A	d	5	1115	100	100	11-2w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Ngale	B	m	50	2136	100	100	11-2w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	B	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Mojosari	B	m	30	1650	100	100	11-2w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	B	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Kendalpayak	B	m	450	1761	100	100-120	11-3w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	B	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Sumberpadas	C	m	80		100	100	11-3w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	C	m	"		"	"	4-8w	-	-	-	4-7	-	-	-	-
Bendo	C	m	200	2468	100	100	11-3w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Geger	C	m	100	2081	75	90	11-2r	11-2r	4-6r	11-7r	11-2	11-2	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	-	3-6r	-	-	-	3-5	-	-	-
Bondowoso	C	m	250	2264	75	90	11-3m	11-2m	4-6m	11-7r	11-2	11-2	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	-	3-6m	-	-	-	3-5	-	-	-
Ringinpitu	C	m	30		100	100	11-3w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	C	m	"		"	"	4-7w	-	-	-	4-6	-	-	-	-
Pasirian	C	m	100	1835	100	80	11-3w	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
"	C	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
							Province: Bali								
Denpasar	A	d	3	1174	100	100	11-2w	4-7m	4-6m	-	11-2	4-6	4-6	-	11-2;4-7
"	A	d	"	"	"	"	3-7w	-	-	-	3-6	-	-	-	-
Grogak	C	m	45	1353	75	100	11-2m	4-7m	4-6m	-	11-2	4-6	4-6	-	11-2;4-7
"	C	m	"	"	"	"	3-7w	-	-	-	3-6	-	-	-	-

Table 2.2 Basic Agroclimatic Data for Selected Provinces in Indonesia (continued)

STATION Name	Type 2)	Reporting frequency 3)	Elevation (m)	Mean Annual rainfall (mm)	Prevailing soil depth (cm)	Capacity of available water in the prevailing soil mm/1m soil	Peak sowing and harvesting months and crop water management practice 4) rice	maize	soybean	cassava	Months for calculating indices and making assessments rice	maize	soybean	cassava	Months for calculating GMI
Province: Bali (continued)															
Sukasada	C	m	150	1476	100	100	11-3w	4-7m	4-6m	-	11-2	4-6	4-6	-	11-2;4-7
"	C	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Abang	C	m	310	2216	100	80-100	11-3m	4-7m	4-6m	11-7r	11-2	4-6	4-6	11-5	11-2;4-7
Province: Nusa Tenggara Barat															
Ampenan	A	d	5	1432	75	100	11-2m	3-6m	3-5m	-	11-2	3-5	3-5	-	11-2;4-7
Sumbawa Besar	A	d	5	1229	75	100	11-2r	-	3-5r	-	11-2	-	3-5	-	11-2;4-7
Taliwang	C	m	5	1523	75	100	11-2r	-	3-5r	-	11-2	-	3-5	-	11-2;4-7
Ampang	C	m	25	1231	75	100	11-2r	-	3-5r	-	11-2	-	3-5	-	11-2;4-7
Province: Sulawesi Selatan															
Ujung Pandang	A	d	15	2900	100	100	11-2w	4-7m	4-6m	-	11-2	4-6	4-6	-	11-2;4-7
"	A	d	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Maros	B	m	5	3154	100	100	11-2w	4-7m	4-6m	-	11-2	4-6	4-6	-	11-2;4-7
"	B	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Malino	C	m	1021	3933	100	100	11-3m	-	-	-	11-2	-	-	-	11-2;4-7
"	C	m	"	"	"	"	4-8w	-	-	-	4-7	-	-	-	-
Watampone	C	m	20	2299	100	100	11-2m	-	-	-	11-2	-	-	-	11-2;4-7
"	C	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-
Palopo	C	m	50	2518	100	100	11-2m	-	-	-	11-2	-	-	-	11-2;4-7
"	C	m	"	"	"	"	4-7w	-	-	-	4-6	-	-	-	-

1) Data for soils and crop calendars represent the best estimate of prevailing conditions in the vicinity of the station.
2) Type A are synoptic stations, observing rainfall, air temperature, wind at 10m height, air humidity and atmospheric pressure.
Type B are climatological stations, observing rainfall, air temperature, wind at 2m height, air humidity, soil temperature, sunshine duration and evaporation from class A pan.
Type C are rainfall stations, observing rainfall only.
3) Reporting frequency "d" means daily, while "m" means monthly.
4) "w"=crops near the station are mostly irrigated; "r"=crops near the station are mostly rainfed; "m"=both irrigated and rainfed fields exist near the station.

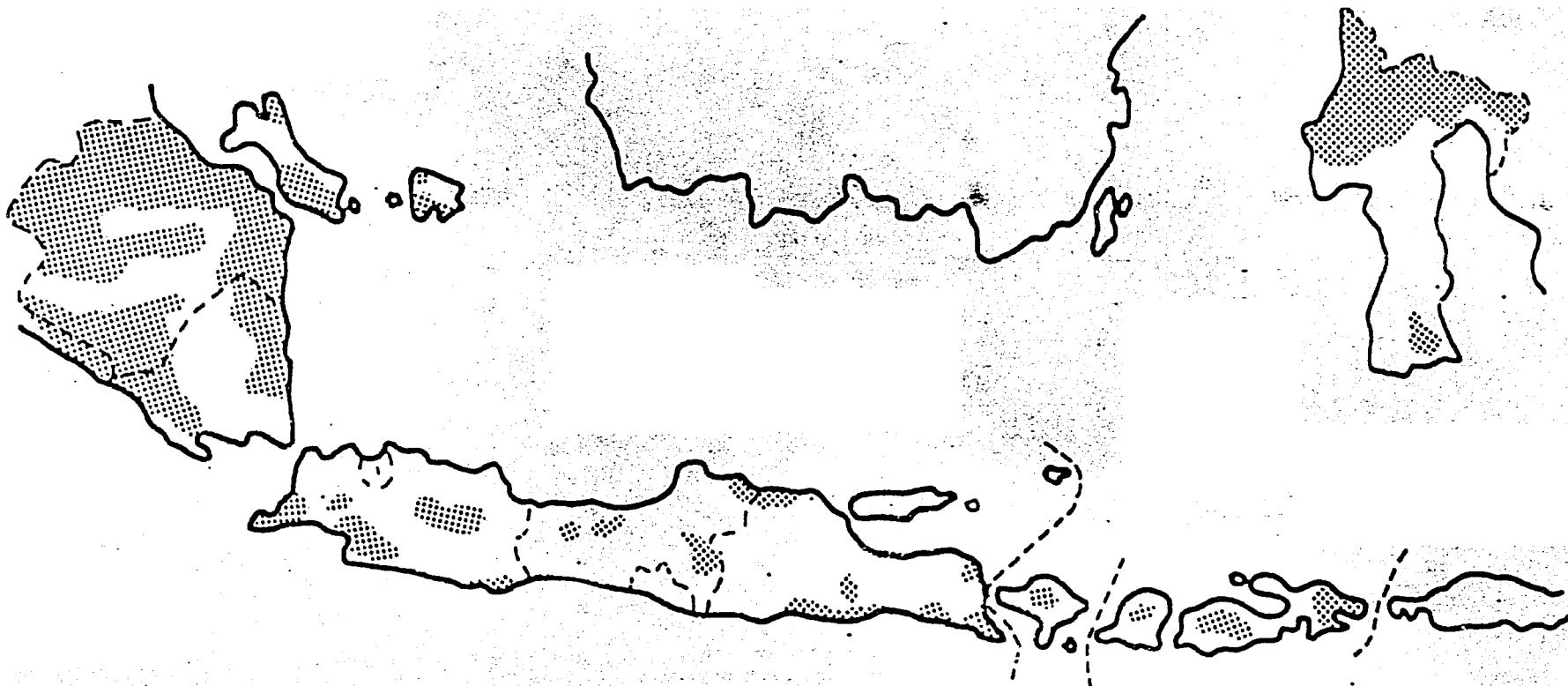


FIGURE 2.3 The Distribution of Forests and Non-agriculture Lands in the Study Area.

Kalimantan and Sulawesi result from farmers clearing the forests, while in Nusa Tenggara Timur, grassland is a natural product of drier climate.

4. Climate

The climate of Indonesia is warm and humid, with uniform temperatures throughout the year. Rainfall is the meteorological element with the highest spatial and temporal variation. The beginning of the rainy season is determined by the position and intensity of the Intertropical Convergence Zone (ITCZ) which, as a component of large scale atmospheric circulation patterns, migrates seasonally across the equator. The rainy season in Sumatra begins normally in October, while over the rest of the country it generally begins in November (Figures 2.4a and 2.4b). The western half of Sumatra also has a well pronounced secondary rainy season that begins in April.

The mean annual rainfall of Indonesia is relatively high. There are numerous inter-provincial and intra-provincial differences in rainfall amounts due to topographic influences. For example, in West Java agricultural areas along the northern coast receive between 1,000 and 2,000 mm annually, while many areas along the southern coast receive between 3,000 and 4,000 mm (Figure 2.5). The mountainous areas are the wettest with annual rainfall in excess of 4,000 mm. The driest areas are found in the province of Nusa Tenggara Barat.

Location and topography affect not only the amount but also the seasonal variations of rainfall. As shown in Figure 2.4a, station Cilacap in the province of Central Java has its monthly peak in November, while station Tegal in the same province peaks in January. Even more important are the intra-provinical differences in South Sulawesi. Station Palopo has a more or less even distribution of rainfall during most of the year, with a peak in May. On the other hand, station Ujung Pandang has a very well pronounced rainy season with a peak in January and an equally well pronounced dry season of several months (Figure 2.4b).

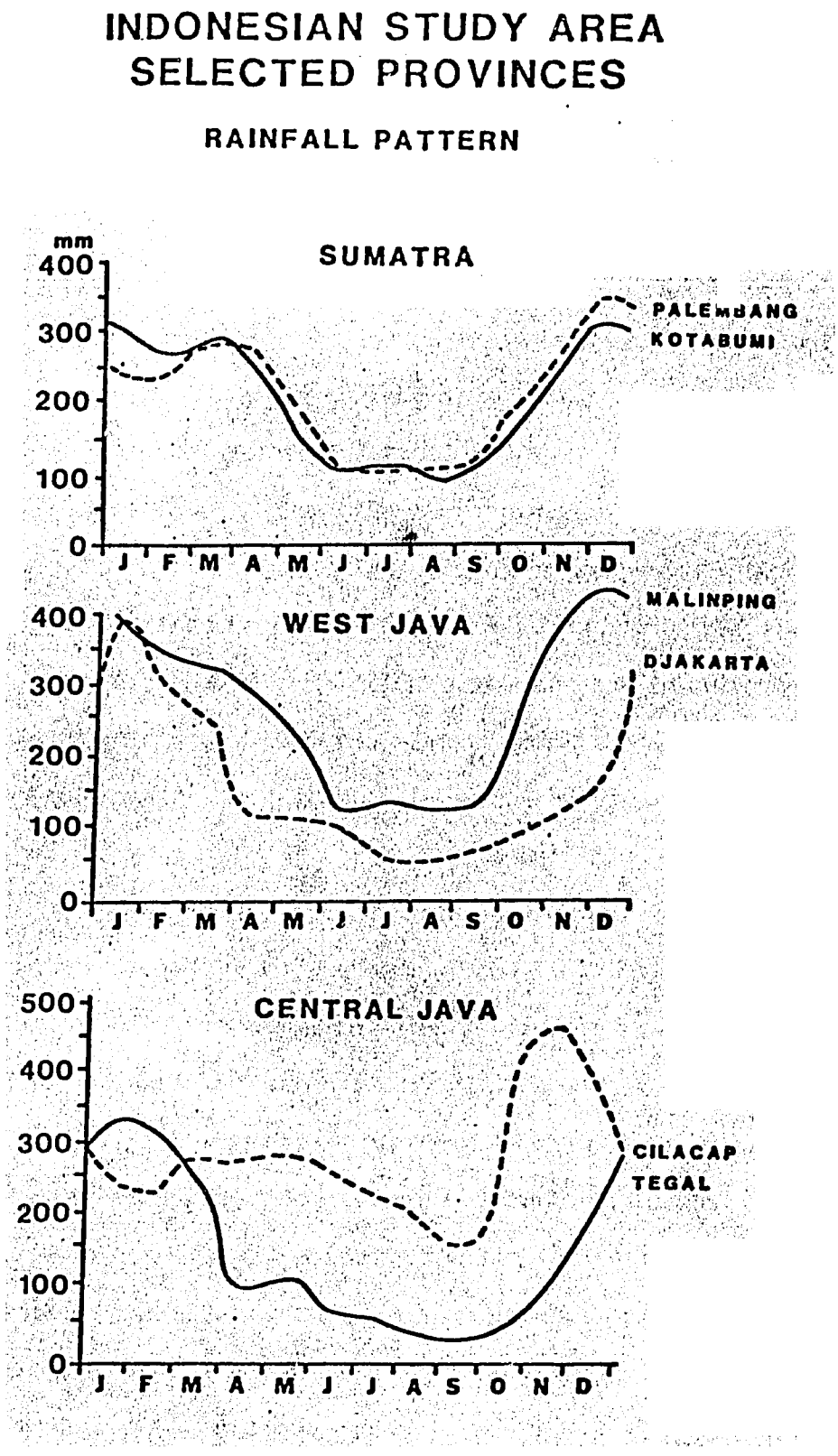


FIGURE 2.4a Rainfall Patterns for Select Stations in the Provinces of Sumatra, West Java and Central Java.

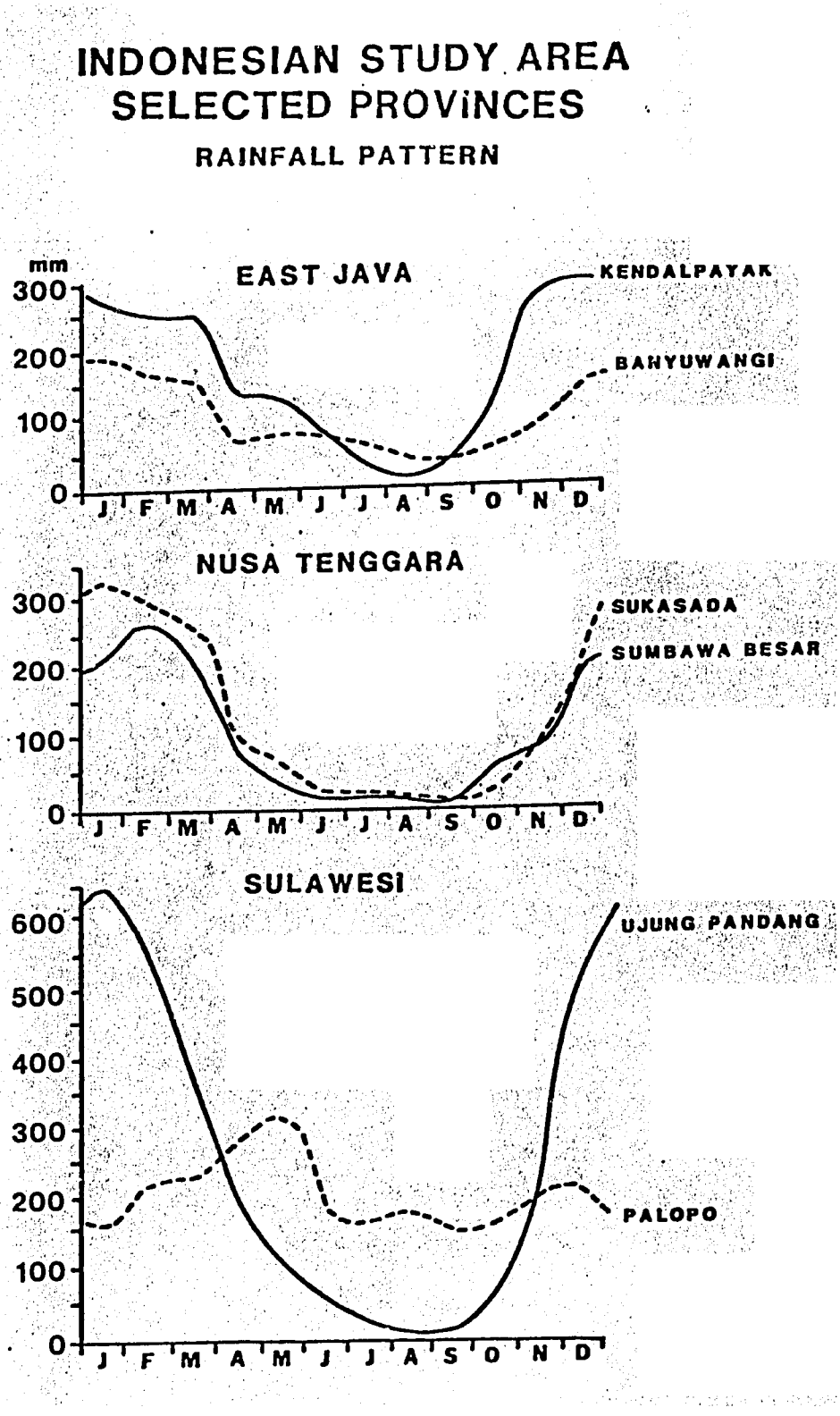


FIGURE 2.4b Rainfall Patterns for Select Stations in the Provinces of East Java, Nusa Tenggara and Sulawesi.

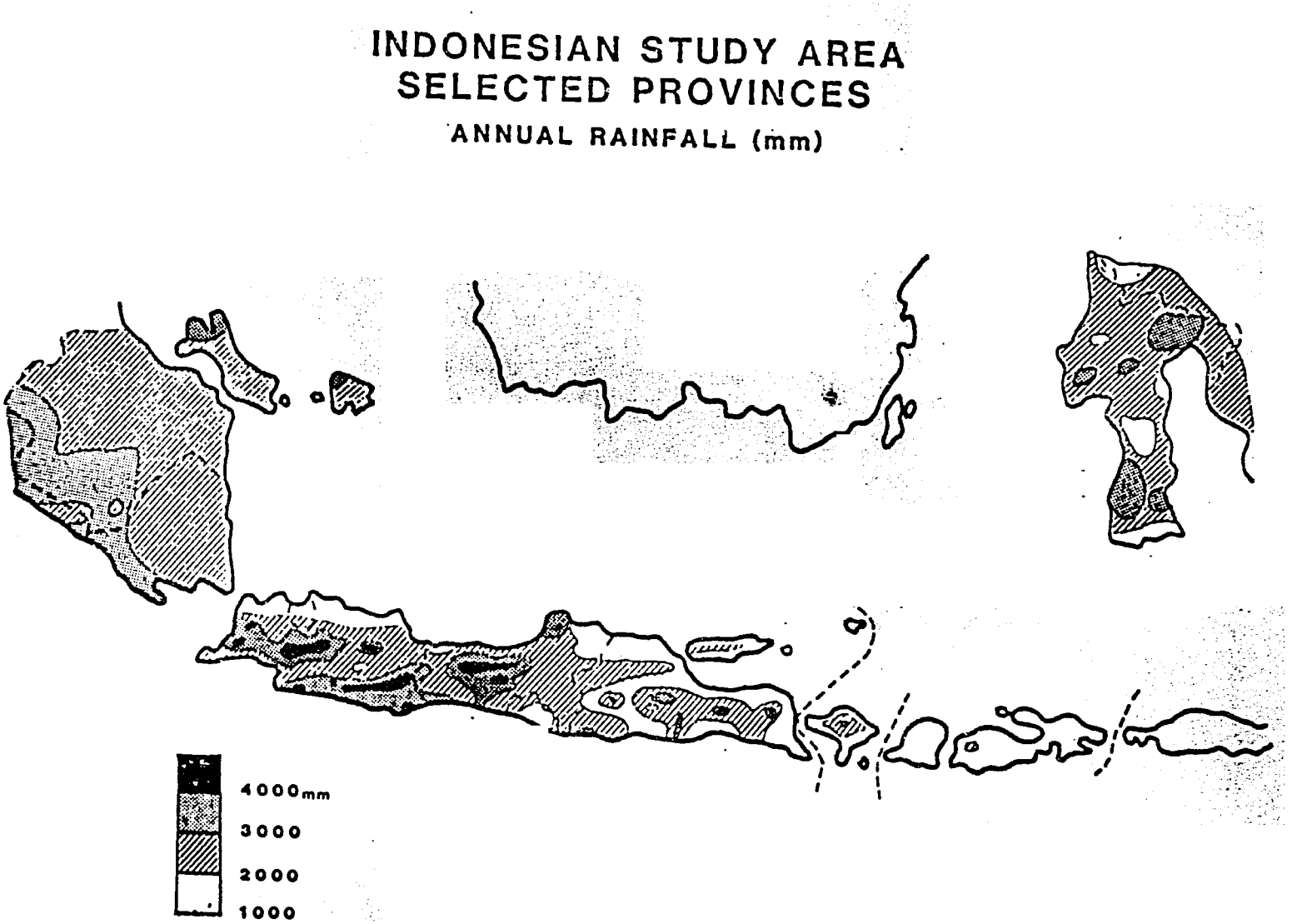


FIGURE 2.5 Annual Rainfall Regimes for Selected Provinces in Indonesia.

The great spatial variability of the rainfall regime in Indonesia indicates that the monthly or decadal assessments of the existing agrometeorological conditions in a province should be done on a station basis. An average amount of rainfall for a whole province has little agrometeorological meaning because drought conditions could exist in some areas while there is excess rainfall in others.

Other meteorological elements such as temperature, sunshine duration, air humidity, etc., are of lesser importance to agriculture than rainfall for Indonesia. They are either quite uniform throughout the year and essentially do not vary from year-to-year, or vary in accordance with rainfall. Mean daily or monthly air temperatures in the lowlands are within the narrow range of 25-28°C throughout the year. A similar narrow range exists for upland locations; however, the temperature is lowered by about 0.6-0.7°C for every 100 m increase in elevation. The diurnal range of temperature is also quite low, on the order of 5-10°C depending on location, due to high night temperatures. This leads to high respiration from agricultural crops, limiting their yield potential.

Sunshine duration data indicate an inverse relationship between monthly or seasonal rainfall and available hours of sunshine. During the rainy season the skies are cloudy, and depending on location, there are 4-6 mean daily hours of sunshine. During the dry season, the mean daily hours of sunshine increase to 6-9. Potential crop yields are influenced by these conditions. For example, yields for irrigated rice grown during the dry season are generally higher than yields for rice grown during the wet season because of the greater availability of solar radiation for use in photosynthesis.

Air humidity in Indonesia has two main features: high values and uniformity throughout the year. The high values are due to the considerable amount of rainfall, as well as to the proximity to the sea. For most lowland areas of

Indonesia, the relative humidity is within the 75-85 percent range. High air humidity, especially during the rainy season, often stimulates the occurrence of some plant diseases and pests.

The most important meteorological hazards in Indonesia are drought, floods and tropical storms. Damages due to drought, however, far exceed those from all other meteorological hazards. Drought affects larger areas, occurs more frequently and causes greater damage. Floods mostly affect agricultural fields along river banks, while storm damages occur mainly on sugarcane plantations.

The climate of Indonesia can be assessed by several different climatic classifications. An example is shown in Figure 2.6, where the rainfall regime is divided into eight categories (IRRI, 1974). Months with mean rainfall amounts in excess of 200 mm are considered "wet", while months with less than 100 mm are considered "dry". The duration of the wet seasons determine the type and number of crops that can be grown in a given area.

5. Agricultural Practices

Indonesia's economy is largely dependent on agriculture. Sixty percent of the working population is engaged in agriculture; agricultural products account for more than half of the national income. Major food crops in order of importance are: rice, maize, cassava, sago, sugarcane, sweet potatoes, yams, peanuts, soybeans and beans. A large variety of vegetables and fruits (including bananas) are also grown. Thirty-five percent of the arable land is used for growing commercial crops, primarily for export. There are more than forty export crops; the most important export crops are rubber, oil palm, tobacco, coffee, tea, coconut, pepper, cacao and cinchona (the base for quinine). The areas where some of these crops are grown are indicated in Figures 2.7 through 2.11.

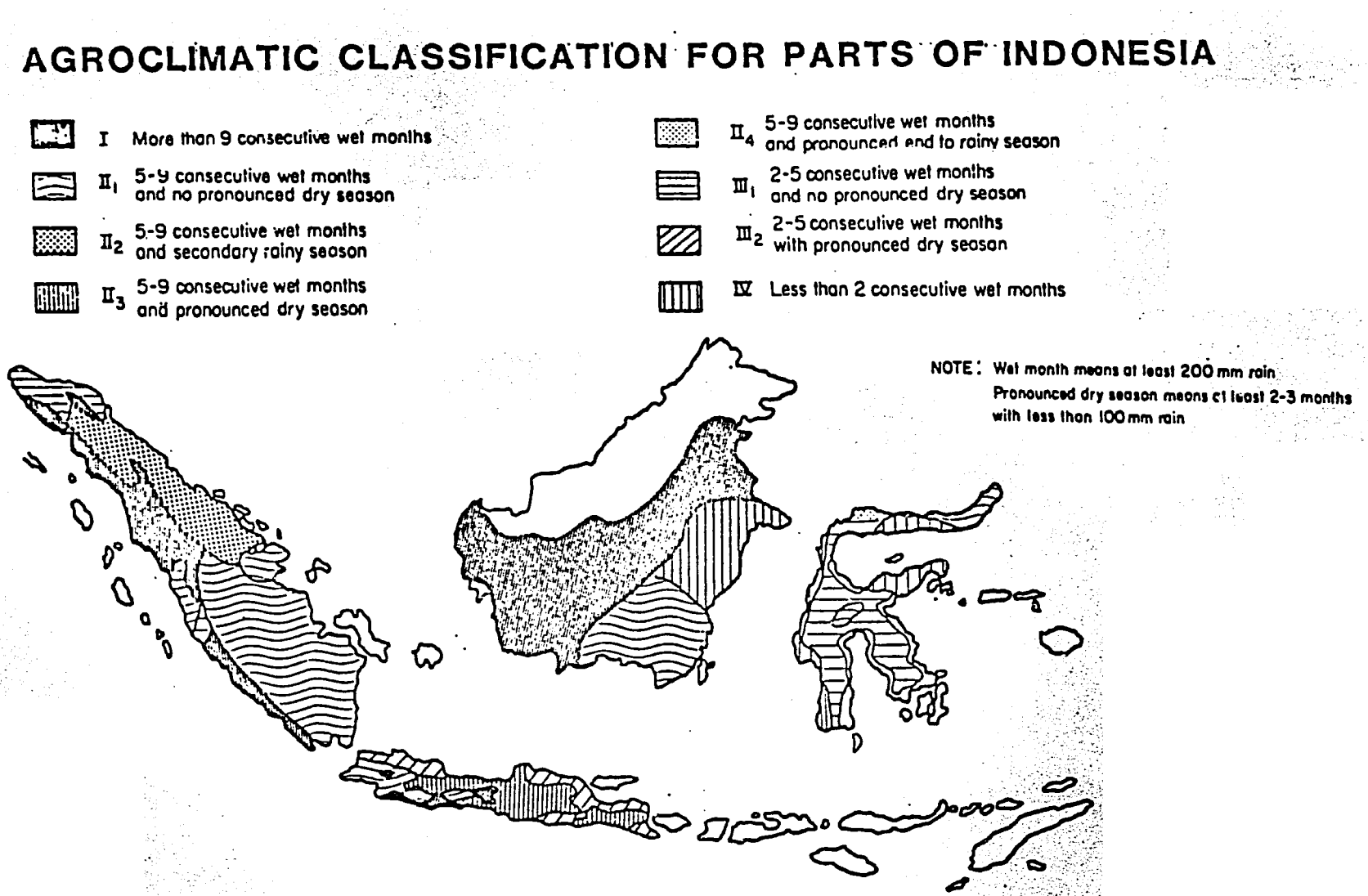


FIGURE 2.6 Agroclimatic Classifications for Parts of Indonesia Based on Rainfall Zones. Source: IRRI (1974)

FIGURE 2.7 Main and Secondary Season Rice Areas in Selected Provinces of the Study Area.

INDONESIAN STUDY AREA
SELECTED PROVINCES
MAIZE AREAS

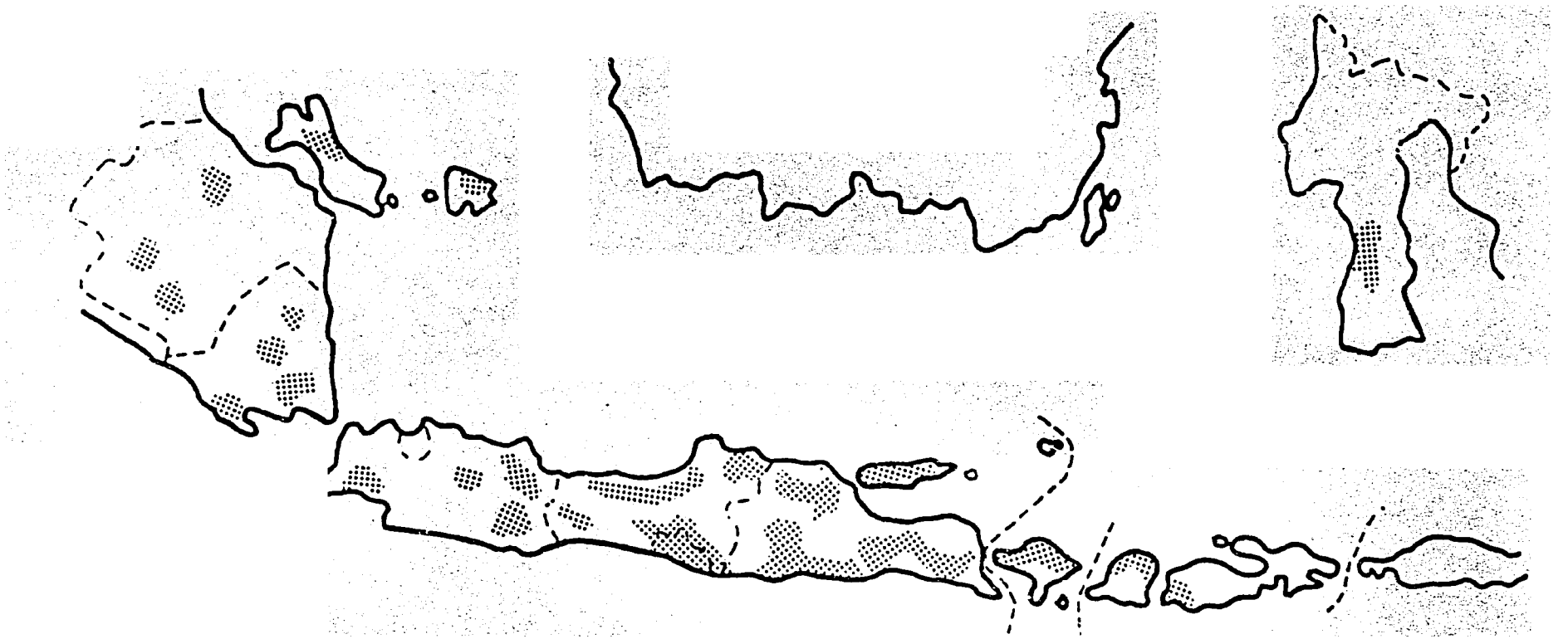


FIGURE 2.8 Maize Areas in Selected Provinces of the Study Area.

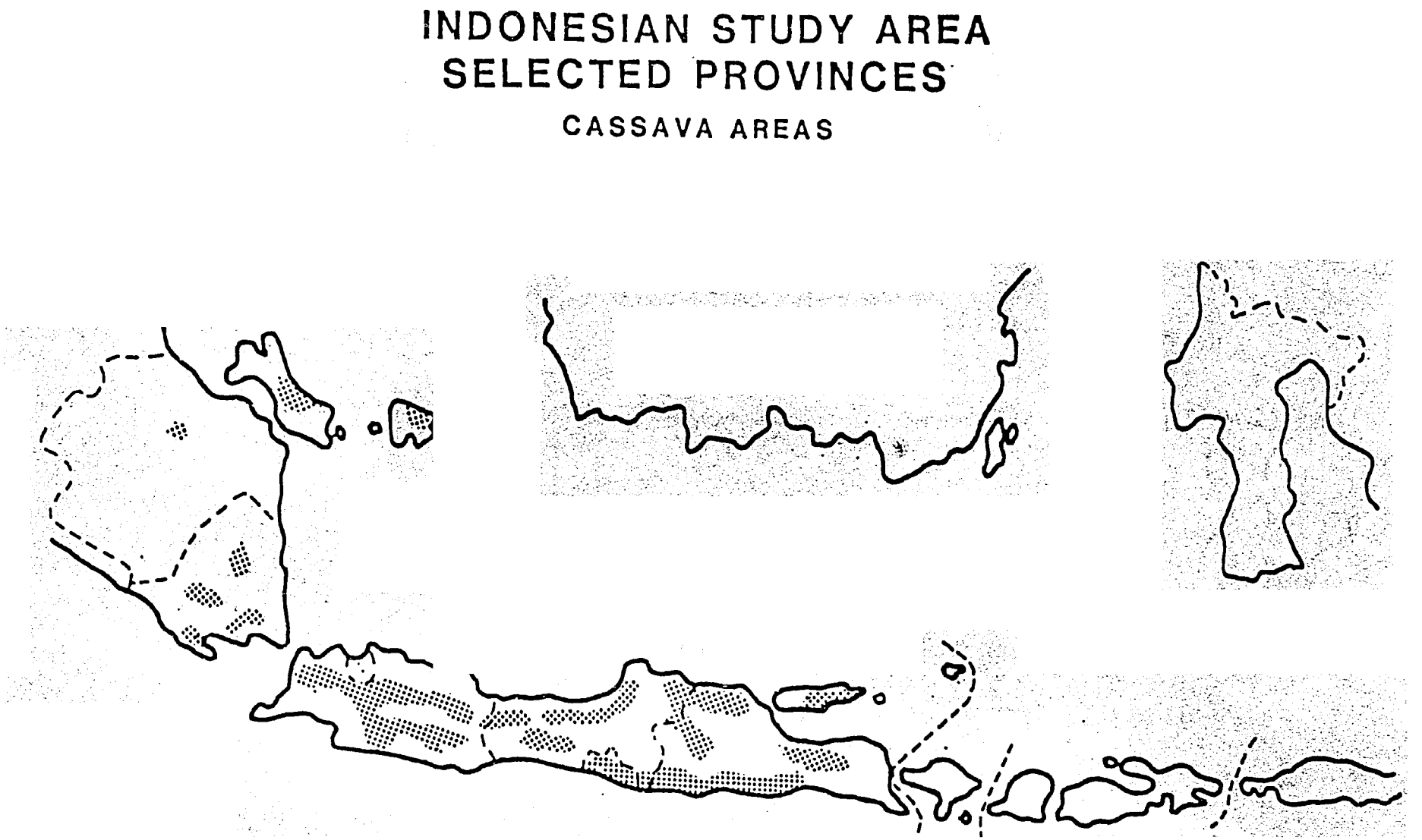


FIGURE 2.9 Cassava Areas in Selected Provinces of the Study Area.

INDONESIAN STUDY AREA
SELECTED PROVINCES
SUGARCANE AREAS

FIGURE 2.10 Sugarcane Areas in Selected Provinces of the Study Area.

FIGURE 2.11 Soybean Areas in Selected Provinces of the Study Area.

Indonesian food imports primarily include rice and wheat. Total imports vary from year to year, depending on the amount of local production. In spite of the various actions taken by governmental authorities, production often does not meet the requirements of the rapidly increasing population. Self-sufficiency in rice is one of the national goals.

Several different agricultural practices are used to produce food crops in Indonesia. Most of these are common throughout Southeast Asia, however, some are unique to Indonesia. These agricultural practices are briefly discussed in terms of their vernacular names.

Sawah refers to irrigated agriculture in which the fields are bunded, i.e., they are surrounded by a soil embankment about 20 to 40 cm high which retains water in the field. Sawah is practiced where the soils are fertile and where irrigation is possible. Normally, rice is the only crop grown in sawah fields. Irrigation water is obtained from rivers or streams by the gravity-flow method. Water control is exercised by permitting the water to flow from one sawah field to the next. When the plants approach full maturity, the fields are completely drained of water. Two and as many as three rice crops can be grown each year by using this method. The yields are stable, but the work is laborious. The distribution of total sawah acreage throughout Indonesia includes 58 percent in Java, 20 percent in Sumatra, 9 percent in Sulawesi, 8 percent in Kalimantan and 5 percent in Bali.

Tegalan refers to non-irrigated permanent fields for annual crops. These fields cannot be irrigated because of their location, e.g., on slopes. Farmers use tegalan methods only when sawah is not possible. In contrast to sawah fields, tegalan fields are planted with different crops including rice, maize, cassava, sweet potatoes, peanuts, and others. Two crops are grown each year in those areas with a long rainy season or with two distinct rainy seasons. Only

one crop is grown in the drier areas. If the soil is not fertile, the farmers will leave the field fallow for one growing season every other year or once in three years. Farmers practice crop rotation, intercropping, mulching, terracing and other agricultural techniques. Tegalan fields are generally located in the same regions as sawah fields, in Java and to a lesser extent in Sumatra, Sulawsi, Kalimantan and Bali.

Ladang refers to shifting or "slash and burn" type agriculture. Rice and maize are the primary crops cultivated on such lands. This type of farming is found mostly in central and north Sumatra, Kalimantan and Irian Jaya where virgin land is still in abundance.

There are two other agricultural systems used primarily in growing commercial crops. The first refers to "perennial gardens" located near sawah fields. These gardens utilize the excess water from the sawah fields. The second system refers to large permanent estates on which crops such as rubber, oil palm, coffee and tea are grown. These estates require a massive investment of capital and technology for their success.

The crop calendars in most Southeast Asian countries are closely related to the local rainfall patterns, however, those in Indonesia are less distinctly defined. The sowing of a crop can take place at any time during the year due to the abundance of water. Farmers generally stagger planting in order to spread their workload more evenly throughout the year. In this report the crop calendars for Indonesia refer to the peak planting or harvesting months. Crop calendars for Indonesia are shown in Table 2.3.

Rice

Rice is the primary food crop for the majority of Indonesians. The harvested area for rice was about 8 million hectares during 1977 (Table 2.4). About 52 percent of all rice is cultivated in Java alone.

Table 2.3 Normal Crop Calendars for the Provinces in Indonesia

PROVINCE	CROP	SEASON	J	F	M	A	M	J	J	A	S	O	N	D
Sumatra Selatan	Rice	Main		0000	0000	0000	0					////	////	——
	Maize	Main	0000	00								////	//	
	Maize	Secondary			//	////	//	0	0000	0				
	Soybean	Secondary			////	///	/	0000	0000	0				
	Cassava	Main						0000	0000	0000		////	////	
Lampung	Rice	Main		0000	0000	0000	0					////	////	——
	Rice	Secondary			//	////	——	0	0000	0000				
	Maize	Main	0000	0000								////	////	
	Maize	Secondary			//	////		0	0000	0				
	Soybean	Secondary			//	////	/	00	0000	00				
	Cassava	Main						0000	0000	0000		////	////	
Jakarta	Rice	Main		0000	0000	00						//	////	——
	Rice	Secondary			//	////	——	0	0000	0000				
Jawa Barat	Rice	Secondary		/	////	////	——	000	0000	0000				
	Rice Trad Varieties				00	0000	0000	00						//// ——
	Rice	Main	0	0000	0000	0							////	//// ——
	Maize	Main	000	0000	00								////	//
	Maize	Secondary			////	////		000	0000	0000				
	Soybean				////	////		0000	0000					
	Cassava	Main							0000	0000		////	////	

NOTES: //// planting 0000 harvesting ____ transplanting

Table 2.3 Normal Crop Calendars for the Provinces in Indonesia (continued)

PROVINCE	CROP	SEASON	J	F	M	A	M	J	J	A	S	O	N	D
Jawa Tengah	Rice	Main	0	0000	0000							//	////	/
	Rice	Secondary			////	////	____	000	0000	0000				
	Maize	Main	00	0000	00							//	////	
	Maize	Secondary		//	////	////		0000	0000	0000				
	Soybean	Secondary			////	////	0	0000	0000					
	Cassava	Main						0000	0000	0000		//	////	
Jawa Timur	Rice	Main	—	0000	0000								////	////
	Rice	Secondary			////	//// /	____	00	0000	0000				
	Maize	Main		0000	0000								////	/
	Maize	Secondary			////	////		0000	0000					
	Soybean	Secondary			////	////	00	0000	0000					
	Cassava	Main						0000	0000	0000		/	////	/
Bali	Rice	Main		0000	0000								////	// ____
	Rice	Secondary			////	//// ____			0000	0000				
	Maize	Secondary			////	////		00	0000	00				
	Soybean	Secondary			///	////		000	0000					
	Cassava	Main						00	0000	0000			////	/

NOTES: //// planting 0000 harvesting ____ transplanting

Table 2.3 Normal Crop Calendars for the Provinces in Indonesia (continued)

PROVINCE	CROP	SEASON	J	F	M	A	M	J	J	A	S	O	N	D
Jogyakarta	Rice	Main		000	0000	00							////	/——
	Maize	Main		000	0000	00							////	
		Secondary			////	////		000	0000	00				
	Soybean	Secondary			////	///	0	0000	00					
	Cassava	Main							0000	0000			////	//
Nusa Tenggara Barat	Rice	Main		00	0000							/	///	
	Maize	Secondary			////	//		0000	00					
	Soybean	Secondary			////		00	00						
Sulawesi Selatan	Rice	Main		0000	0000							//	////	/——
	Rice	Secondary			////——	////——		00	0000	0000				
	Maize	Secondary			//	////		0	0000	00				
	Soybean	Secondary			//	////		0000	00					
Sulawesi Tenggara	Rice	Main	——		0000	0000							////——	////——
	Rice	Secondary				////——	////——			0000	0000	00		
Sulawesi Tengah	Rice	Main		0000	0000	00						////——	////——	
	Rice	Secondary			////——	////——			0000	0000	00			
Sulawesi Utara	Rice	Main		0000	0000	00						////——	////——	
	Rice	Secondary			////——	////——			0000	0000	00			
Kalimantan Selatan	Rice	Main		0000	0000	0						//	////——	
	Rice	Secondary			////——	////——			0000	0000	0			
Kalimantan Tengah	Rice	Main	——		0	0000	0000						////——	//——
	Rice	Secondary				////——	////——			0	0000	0000		

NOTES: //// planting 0000 harvesting —— transplanting

Table 2.3 Normal Crop Calendars for the Provinces in Indonesia (continued)

PROVINCE	CROP	SEASON	J	F	M	A	M	J	J	A	S	O	N	D
Kalimantan Timur	Rice	Main		0000	0000	0000						////	////	———
D.I. Aceh	Rice	Main		0000	0000	00						////	////	———
	Rice	Secondary			////	////	———		00	0000	0000			
Sumatra Utara	Rice	Main		00	0000	0000						//	////	// ———
	Rice	Secondary			//	////	/ ———			0000	0000 00			
Sumatra Barat	Rice	Main	// ———		0000	0000	00						//	////
	Rice	Secondary			//	////	/ ———			0000	0000 00			
Bengkulu	Rice	Main		0000	0000	00						//	////	———
Jambi	Rice	Main	// ———		0000	0000							//	//// ———
		Secondary			//	////	/ ———				0000	0000 00		

NOTES: //// planting 0000 harvesting ——— transplanting

Table 2.4 Rice Statistics for 1977

	Irrigated		Non-Irrigated		Total	
	Java Only	Indonesia	Java Only	Indonesia	Java Only	Indonesia
Area harvested (ha)	4,150,000	7,210,000	240,000	1,180,000	4,390,000	8,390,000
Production rough paddy (tons)	13,354,000	21,909,000	347,000	1,534,000	13,702,000	23,443,000
Yield (tons/ha)	3.22	3.04	1.44	1.30	3.12	2.77

Nearly 86 percent of the total harvested rice area is irrigated (Table 2.4). The yield from irrigated rice (slightly over 3 metric tons per hectare and are of the highest in Southeast Asia) is about 2.5 times higher than that of non-irrigated rice.

Although about 35 percent of the arable land in Indonesia is devoted to rice, it's distribution is not uniform (Figure 2.7). For example, very little rice is grown in the Maluku Islands, the eastern half of Nusa Tenggara and Triar Jaya. More than half of Indonesia's rice acreage is in Java, located mostly in the northern and western regions. Java's climate and fertile soils favor rice cultivation. Runoff from the mountains deposits fertile silt in the lowland fields. There is very little non-irrigated rice in Java as most of it is of the sawah type. The non-irrigated rice fields are located mainly in Jogjakarta and Bantam. The other major rice producing regions are Sumatra, Sulawesi and the western Nusa Tenggara Islands (Bali, Lombok and Sumbawa).

The main rice crop is sown in nurseries with the beginning of the rainy season. In Sumatra and Western Java, sowing usually starts in early October. In Central Java sowing begins in the middle of October, while in Eastern Java and Nusa Tenggara it begins in early November (Table 2.3). Until 5-6 years ago, sowing continued for 2½ - 3 months. After the replacement of the old traditional rice varieties with modern high yielding ones, and at the encouragement of agricultural authorities in the country, the sowing period has been reduced to 1½ - 2 months. As a result of this, ripening of the plants is also spread over a shorter period. As the new varieties have a shorter growing period, harvesting of the main rice crop in recent years takes place during February-April in Sumatra and February-March in the other islands.

The secondary rice crop is generally sown during March and April; harvesting occurs from the second half of June through August (Table 2.3). If the main rice crop is to be rotated with the secondary rice crop then the farmers need 3 to 4 weeks before sowing can take place.

The dry-upland rice crop is grown under rainfed conditions. Sowing of this crop is generally very uniform throughout Indonesia, beginning soon after the onset of the main rainy season. Sowing generally begins during October in Sumatra, and in November over the rest of the country. Harvesting, depending on the variety, follows 3 to 4 months after sowing.

Maize and Other Food Crops

Maize is the principal food crop for Lombok, Timor, parts of Sulawesi and eastern Java where more than 25 percent of the cultivated land is planted to maize. The annual production in Java is 2 to 2.5 million tons. These are the only regions throughout Southeast Asia where maize is the main food for such a large portion of the population. Maize is either the second (after rice) or the third staple in order of importance as a food crop for other areas in Indonesia.

Although maize is grown throughout Indonesia, most of the major acreage is in areas where it is the principal food. It is usually planted as an upland non-irrigated crop, i.e., grown on tegalan fields, although it is also grown in sawah fields after the harvest of the main rice crop, particularly in eastern Java. If there is not enough water for a secondary rice crop, farmers plant maize in the sawah fields. Some irrigation during the growing period may be provided. Figure 2.12 shows areas where the rice crop is rotated with either maize or soybeans.

Normally, there is only one maize crop per year and the growing period coincides with the main rainy season in the country. Sowing of the seeds in Java begins in September, while in Nusa Tenggara and Sumatra it begins in October.

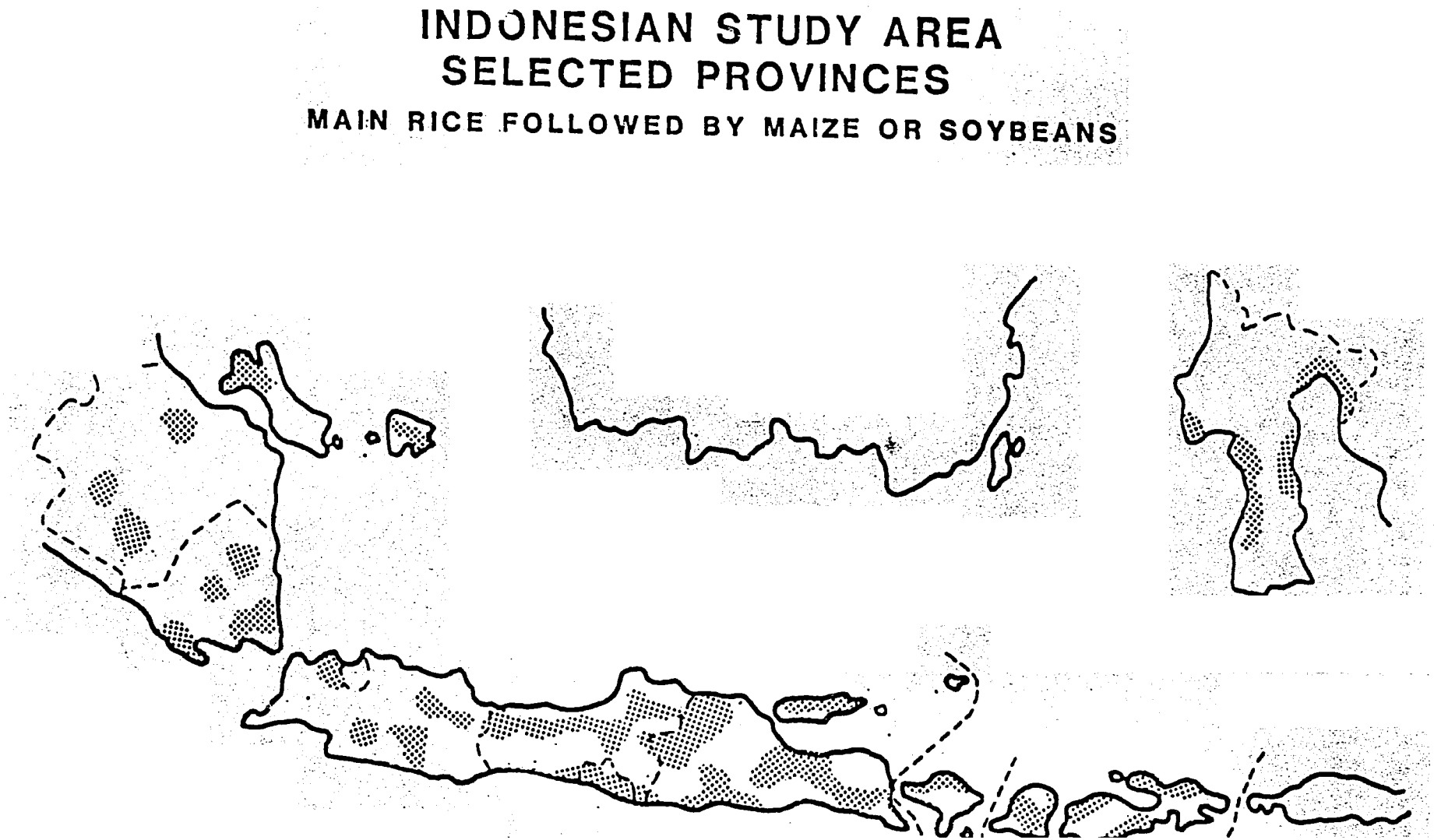


FIGURE 2.12 Areas Where the Main Rice Crop is Rotated With Either Maize or Soybeans.

Sowing usually continues for 2 to 3 months. Because the duration of the growing period is 100-110 days, harvesting in Java begins in mid-December and during mid-January in Nusa Tenggara and Sumatra.

Other important food crops are root crops such as cassava (a perennial), sweet potatoes and yams. Cassava is grown in many areas of Indonesia and is an important cash crop. The total acreage in the late 1970's varied between 1.4 and 1.5 million hectares, with about 75 percent in Java. Major cassava growing areas in Java are Surakarta, Madiun and Kediri, all in the southeastern part of the island. The yield has fluctuated between 7.5 and 9.0 tons per hectare. The total production of fresh cassava roots has varied between 11 and 13 million tons. Sweet potatoes are the principal staple food in the highlands of Irian Jaya.

Factors Affecting Yield

Agricultural production in Indonesia is affected by various weather and non-weather factors. Drought and floods are very important as they occur somewhere in the country each year. The areas most vulnerable to drought include the more arid regions in eastern Indonesia, regions southeast of Jogjakarta on Java Island, and Lombok in Nusa Tenggara. Floods are most commonly observed in the western regions of Indonesia.

Irrigated crops can be damaged by drought, flood or erratic rains either within the crop growing areas or in the neighboring mountains where catchments feed the rivers and streams used for irrigation.

The Brown Plant-Hopper represents the third most important factor adversely affecting rice yield. This pest has spread throughout Indonesia during the last 7-8 years. Continuous cropping of rice in the same fields tends to increase vulnerability. Damages to crops are also caused by rats and some plant diseases.

Fertilizer use increased until the mid-1970's when higher prices sharply reduced fertilizer imports. This in turn reduced the yield response of HYV's which realize their higher yield potential only if nutrients are in adequate supply. Progress has been made in building or improving irrigation and drainage facilities; however, the prevailing agricultural practice is to use the techniques known for decades.

CHAPTER III

METHODOLOGY AND ANALYTIC RESULTS

A. Data Sources

1. Meteorological Data

The meteorological data used in this study were obtained from various types of stations located in Indonesia as shown in Figure 3.1. The period of record for each of these stations is shown in Table 3.1. These meteorological stations were classified as follows:

Synoptic Stations: Monthly rainfall, air temperature, air humidity, wind speed at 10 meters, sunshine duration, and atmospheric pressure data for 16 synoptic stations (Figure 3.1) is available on a real-time basis.

Climatological Stations: Monthly meteorological data from 11 stations were also included in the analysis. The available data included rainfall, air temperture, relative humidity, sunshine duration, soil temperature, wind at 2 m height and Pan Evaporation.

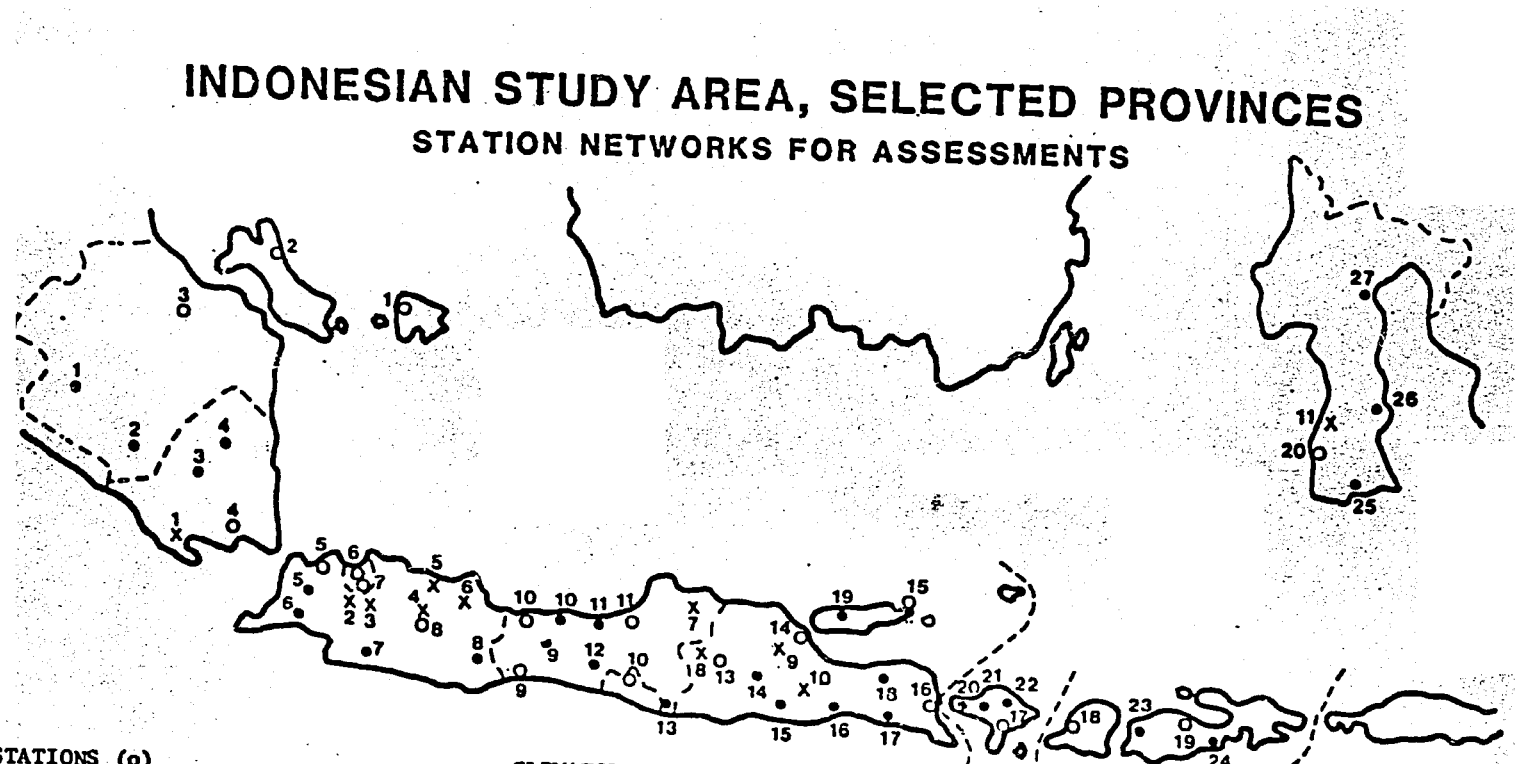
Rainfall Stations: Additionally, 27 rainfall stations (Figure 3.1) were also incorporated into the meteorological database. However, data from these stations is not readily available on a real-time basis due to delays in publishing.

2. Agronomic Data

Area, production, and yield data for maize, wetland and dryland paddy, cassava, soybeans, peanuts, and sweet potatoes was obtained from the Bureau of Statistics in Indonesia. The period of record of this data set was 1968-79. Table 3.2 shows the provinces for which the crop data is available.

3. Episodic Events

Selected episodic events occurring in Indonesia are shown in Table 3.3. These events include both weather and non-weather impacts on agriculture. Both



SYNOPTIC STATIONS (o)

1. Tanjungpandan
2. Pangkalpinang
3. Palembang
4. Telukbetung
5. Serang
6. Kemayoran
7. H. Perdanakusuma
8. Bandung
9. Cilacap
10. Tegal
11. Semarang
12. Adisueipto
13. Madiun
14. Surabaya/Tg. Perak
15. Kalianget
16. Banyawang
17. Denpasar
18. Ampenan
19. Sumbawa Besar
20. Ujung Pandang

CLIMATOLOGICAL STATIONS (x)

1. Tamanbogo
2. Muara
3. Cipanas
4. Margahayu
5. Pusaka Negara
6. Kuningan
7. Jakenan
8. Nyale
9. Mojosari
10. Kendalpayak
11. Maros

RAINFALL STATIONS (•)

1. Baturaja
2. Kasui
3. Kotabumi
4. Menggala
5. Pandeglang
6. Malinping
7. Agrabinta
8. Tasikmalaya
9. Bongas
10. Pekalongan
11. Waleri
12. Magelang
13. Wuryantoro
14. Sumberpadas
15. Bendo
16. Pasirian
17. Ringinpitu
18. Bondowoso
19. Geger
20. Grogak
21. Sukasada
22. Abang
23. Taliwang
24. Ampang
25. Malino
26. Watampone
27. Palopo

FIGURE 3.1 Station Networks Used in Assessments of the Indonesia Study Area.

Table 3.1 Period of Record for Meteorological Stations in the Study Area

STATION	PERIOD OF RECORD
Synoptic	
1. Tanjungpandan	1975-80
2. Pangkalpinang	1975-80
3. Palembang	1951-77
4. Telukbetung	1976-77
5. Serang	1978,80
6. Kemayoran	1975-80
7. H. Perdanakusuma	1975-80
8. Bandung	1953-77
9. Cilacap	1975-80
10. Tegal	1977-80
11. Semarang	1975-80
12. Adisueipto	1975-80
13. Madiun	1976,77
14. Surabaya/Tg.Perak	1975-80
15. Kalianget	1975-80
16. Banyuwangi	1975-80
17. Denpasar	1971,75-77
18. Ampenan	1978
19. Sumbawa Besar	1978
20. Ujung Pandang	1977

STATION	PERIOD OF RECORD
Climatological	
1. Tamanbogo	1977-81
2. Muara	1973-81
3. Cipanas	1973-81
4. Margahayu	1973-81
5. Pusaka Negara	1973-81
6. Kuningan	1973-81
7. Jakenan	1976-81
8. Ngale	1976-81
9. Mojosari	1973-81
10. Kendalpayak	1975-81
11. Maros	1975-81

Table 3.1 Period of Record for Meteorological Stations in the Study Area (continued)

STATION	PERIOD OF RECORD
Rainfall	
1. Baturaja	1951-62, 1971-76
2. Kasui	1952,53 1972-75
3. Kotabumi	1951-76
4. Menggala	1976,77
5. Pandegland	1950-76
6. Malinping	1950-76
7. Agrabinta	1952-76
8. Tasikmalaya	1951-76
9. Bongas	1950-76
10. Pekalongan	1950-76
11. Waleri	1950-76
12. Magelang	1951-75
13. Wuryantoro	1951-77

STATION	PERIOD OF RECORD
Rainfall (continued)	
14. Sumberpadas	1951-76
15. Bendo	1958-76
16. Pasirian	1951-76
17. Ringinpitu	1950-76
18. Bondowoso	1951-76
19. Geger	1951-76
20. Grogak	1951-76
21. Sukasada	1950-76
22. Abang	1952-76
23. Taliwang	1953-76
24. Ampang	1954-76
25. Malino	1952-76
26. Watampone	1950-76
27. Palopo	1951-76

Table 3.2 Provinces for Which Area, Production and Yield Data (1968-1979) for Wetland and Dryland Paddy, Maize, Cassava, Soybeans, Peanuts and Sweet Potatoes are Available.

PROVINCE	PROVINCE
SUMATRA	KALIMANTAN
1. D.I. Aceh	17. Kal. Barat/West Kalimantan
2. Sumatera Utara/North Sumatra	18. Kal. Tengah/Mid Kalimantan
3. Sumatera Barat/West Sumatra	19. Kal. Selatan/South Kalimantan
4. Riau	20. Kal. Timur/Fast Kalimantan
5. Jambi	SULAWESI
6. Sumatera Selatan/South Sumatra	21. Sulawesi Utara/North Sulawesi
7. Bengkulu	22. Sulawesi Tengah/Mid Sulawesi
8. Lampung	23. Sulawesi Selatan/South Sulawesi
JAWA & MADURA	24. Sulawesi Tenggara/S.E. Sulawesi
9. D.K.I. Jakarta	MALUKU & IRIAN JAYA
10. Jawa Barat/West Java	25. Maluku
11. Jawa Tengah/Mid Java	26. Irian Jaya
12. D.I. Yogyakarta	OUTER JAVA
13. Jawa Timur/Fast Java	27. Juml. Luar Jawa/Total Outer Java
BALI & NUSATENGGARA	
14. Bali	
15. Nusatengg. Barat/West Nusatengg.	
16. Nusatengg. Timur/Fast Nusatengg.	

TABLE 3.3

INDONESIA

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

YEAR	EPISODIC EVENT
1955	Maize Damaged from Excessive Rainfall in Java
1958	Agricultural Production Affected by Civil Disturbances
1959	Despite Floods and Pests, Production was Good
1961	Floods Caused Damage
1961	Famine Conditions Reported in Java and Lombok
1961	Severe Drought in Java (Relief Assistance)
1961	Drought Conditions in Much of Java and South Sumatra Affected the Second Rice and Most Other Crops. The Drought Led to Famine in Java During 1962 (Relief Assistance)
1962-63	Floods Affected Production, Adverse Weather Delayed Planting, Uneven Rainfall During the Growing Season
1964	Crops Plagued by Floods and Rats with Drought in East and Central Java
1966	Severe Drought in Lombok
1967	Drought Badly Affected Rice
1968	Drought and Management Hampered Crop Production
1972	Drought Reduced Rice Production by 8 Percent. October-November Sowing of Maize and Rice Delayed in Central Java and Nusa Tenggara
1973	Drought and Brown Plant-Hopper Damage to Crops
1974	Pests Affected Rice Yield
1975	Pest Damage Especially Due to Brown-Plant Hopper

TABLE 3.3

INDONESIA CONTINUED:

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

YEAR	EPISODIC EVENT
1976	Drought and Plant Diseases Decreased Maize Yield. Flooding Around Djakarta. Insects. Drought During July in West Java. Drought in October Affected Planting of Secondary Rice. Floods in Sumatra During October Damaged Rice Fields. Drought in Central Java During October. Floods in East Java During November. Floods in Northwest Sumatra During December
1977	Floods in East and Central Java During March. Pests and Drought in Lombok During September. Floods in East Java During December. Drought in West Java During October
1978	Floods in East and Central Java During January. Drought in East Nusa Tenggara During April. Heavy Floods During May in Northwest Sumatra
1979	Floods in Sumatra and in Djakarta. Rats in West Java. Floods During April in East and West Java. Upland (Rainfed) Rice and Maize Affected by Drought During July, August and September. Heavy Floods in Kalimantan During December
1980	Floods in South Sumatra During January
1981	Drought in October Delays Sowing in West Sumatra
1982	Drought Affects Secondary Crops in Java, and Delays Sowing of the 82/83 Main Rice Crop

drought and flooding can seriously affect crop production. Drought during the critical flowering or reproductive stage of the crop is quite harmful. Weather impact due to flooding usually occurs during heavy monsoon rains and tropical depressions.

Sometimes weather indirectly affects the crop by creating favorable environmental conditions for both pest and plant disease outbreaks.

Such episodic event data can be qualitatively used in statistical crop yield modeling to determine possible reasons for fluctuations in crop yield or production data. Episodic event data can also be used to select and interpret agroclimatic indices such as the Palmer Drought Index (PDI), Yield Moisture Index (YMI), and Generalized Monsoon Index (GMI).

4. Capabilities and Limitation of Data

The meteorological data used in this study are of good quality. The monthly mean rainfall data are determined from at least 28 daily observations while the monthly mean temperature and humidity are obtained from at least 25 daily observations. Quality control of the monthly meteorological data was undertaken to delete erroneous cases. Observations were compared to their normal and with other meteorological elements.

One of the limitations in using monthly instead of daily data is that monthly data do not indicate the distribution of rainfall during the month. The assumption for using monthly data is that rains are evenly distributed during the period. This assumption may not always be valid.

The source of all the yield data is the Bureau of Statistics in Indonesia. Data were collected through their surveys and from other sources. Fluctuations in the yield data result from both weather and non-weather impacts. Year-to-year variations in yield are usually associated with drought, flooding and pests in the study area. There is also evidence that changes in technology cause changes in yield.

B. Analytic Methods

1. Rainfall

Monthly rainfall data available from each weather station were averaged to obtain the distribution of the monthly means (Figure 2.4). The seasonal rainfall during November through February is dominant over all regions in Indonesia. There is a small secondary peak in rainfall during March and April for stations such as Palembang and Kotabumi in Sumatra, Kendalpayak and Banyuwange in East Java, and Sukasada and Sumbawa Besar in Nusa Tenggara.

2. Potential Evapotranspiration (PET)

Evapotranspiration is defined as the sum of the evaporation of water directly from the surface of water, soil and vegetation and the transpiration of plants. If soil water is not limiting, the evapotranspiration from a complete plant canopy is called the potential evapotranspiration (PET).

There have been many methods proposed for estimating PET from meteorological data. One of the simplest models is to approximate PET as 80 percent of pan evaporation (from U.S. Class A pan). Some of the other major estimation methods follow.

<u>Penman Method (1948)</u>

Penman's method is derived from the physical laws governing the the evapotranspiration process. The approach involves making an empirical estimate of the transfer of mass (water vapor) from a wet surface and incorporating this estimate into an expression defining the surface energy budget. The Penman formula for the rate of PET from an extensive and uniform wet surface can be written as:

$$PET = (mH + 0.66\ Fa)/(m + 0.66)$$

where: PET is the potential evapotranspiration (mm/day),

m is the slope of the saturation vapor pressure curve for water at mean temperature in mb/°C,

H is the net radiation in evaporation equivalent of mm/day,

0.27 is the psychrometric constant in mb/°C, and

E_a is $0.26\ (e_s - e_a)(1 + 0.54\ U_2)$ mm/day

with e_s the saturation vapor pressure (mb) at the mean air temperature,

e_a the actual vapor pressure (mb), and

U_2 the mean wind speed at 2 meters in m/sec.

The main problem with the Penman method is that the data for net radiation, vapor pressure deficit, and wind speed are not readily available for most meteorological stations. Because of incomplete meteorological data at most weather stations, other empirical methods for estimating PET have also been proposed.

Thornthwaite Method

Thornthwaite (1948) derived an empirical relationship between PET and mean temperature. PET is expressed as an exponential function of mean monthly air temperature or,

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

where: PET is the potential evapotranspiration (cm/month),

T is the mean monthly air temperature (°C),

I is a heat index which represents the sum of 12 monthly indices and may vary from 0-160,

$$I = \sum_{i=1}^{12} (T_i/5)^{1.514}$$

A is a cubic function of I for a given location which may vary from 0-4.25 and is defined as:

$$A = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.79 \times 10^{-2}\ I + 0.49.$$

The values of PET are for a day length of 12 hours and a 30 day month; an adjustment must be made to estimate PET for a particular month and location.

This method has been used worldwide because temperature and the local latitude are the only variables required. However, this method has received considerable criticism because the mean air temperature does not relate to the surface energy balance. Also, the method was designed only for making monthly PET estimates.

Hargreaves Method

Hargreaves (1977) used air temperature and solar radiation as the main meteorological elements to estimate PET as follows:

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

where: PET is the potential evapotranspiration (mm/day),

RSM is solar radiation (mm/day), and

TF is the daily mean temperature (°F).

When solar radiation is not available, it can be estimated from sunshine hours and extraterrestial radiation.

Adjusted Pan Evaporation Data

Potential evapotranspiration estimates can be obtained by adjusting pan evaporation observations by a factor of 0.8 (80 percent of pan value). This ratio can be used to approximate potential evapotranspiration from pan evaporation data.

Evaluating Methods for Estimating PET

Because PET is one of the fundamental agroclimatic analysis tools for the study of moisture stress on crops, reliable estimation methods must be identified. This is often difficult even with optimum data. The previously discussed methods provide PET estimates. These contrast with measured PET which is usually determined by field experiments using a lysimeter.

In this study for Indonesia, monthly data from the agrometeorological stations were used to estimate PET by the Penman, Hargreaves, and Thornthwaite methods. These were compared to each other and to 80 percent of pan evaporation. The sample means, variances and time-series of individual monthly estimates were compared.

Because actual measurements of PET are not available, definite conclusions cannot be made. However, some inferences can be drawn from comparisons with pan evaporation. Crop calendar information can also be used to interpret PET (moisture demand) and rainfall (moisture supply) relationships. If crops are to be successfully grown in most years, rainfall should generally exceed PET during the crop growing season. If estimated PET during the crop season is consistently larger than rainfall, the PET method is suspect for that region. The Penman Method and pan evaporation data provide reliable PET estimates.

One disadvantage common to all methods is that baseline data are not usually available to confirm the appropriate method. Also, the data for the Penman method are not always available. Finally, some of the methods may be totally inappropriate for climatic conditions in Indonesia.

In spite of these limitations, recommended procedures need to be developed for test and evaluation. The most "appropriate" method needs to be determined. Alternative methods or ways to adjust PET estimates to conform with the "appropriate" method are required. Interpolating PET to data sparse locations is important. Determining when PET normals can be used instead of individual monthly (or weekly, etc.) values is also necessary. For example, if the variance of rainfall is much greater than the variance of PET, then possibly PET normals will suffice. These are some of the questions to be investigated.

3. Soil Moisture Budgeting

The growth and development of crops depend on the water available for their consumption. The sources of the water include rainfall, water stored in the

soil, and irrigation. Precipitation recharges soil moisture in successive soil layers from the surface downward. Precipitation in excess of that required to bring the crop root zone to the water holding capacity is removed by lateral runoff and percolation. For a short dry spell, even without irrigation, crops are not seriously affected even in the critical growth period if there is sufficient soil moisture to support the demand for water. Thus, the soil moisture level may be as good or better an indicator of crop conditions as rainfall. Since soil moisture is difficult to measure directly in the field, several methods have been proposed for estimating its value. Descriptions of two of them follow.

One-Layer Water Balance Method

Thornthwaite's model is based on simple water balance equations for gains and losses within a single layer as follows:

$$S_i = S_{i-1} + P_i - PET_i \ (S_{i-1}/FC)$$

where: S_i is the soil moisture estimate for the current period,

S_{i-1} is the soil moisture for the previous period,

P_i is the precipitation,

PET_i is potential evapotranspiration for the current period, and

FC is the field capacity of the soil.

Two-Layer Method

In contrast to the one-layer model, Palmer (1965) proposed a two-layer model which makes the following assumptions:

1) The upper layer is equivalent to the plough layer and is assumed to hold about 2.5 cm of plant available water. The soil water in the surface layer (SS) is lost at a potential rate.

2) The underlying layer extends from the base of the plough layer to the depth of rooting for a particular crop. Soil water in the underlying layer (SU)

is lost at the potential rate when the profile is at field capacity. The available water in this layer depends on the depth of the root system and on the soil characteristics.

The soil moisture budget is:

$$S_i = SS_i + SU_i = SS_{i-1} + SU_{i-1} + P_i - AET_i - RO_i$$

where: SS_i and SU_i are the soil water in the surface and underlying layers, respectively,

i is the current time period and $i-1$ is the previous time period,

S_i is the soil water in both surface (SS_i) and underlying (SU_i) layers,

P_i is the rainfall received during the current time period,

AET_i is the actual water loss by evapotranspiration, and

RO_i is the runoff.

The actual water losses by evapotranspiration and runoff are estimated by:

a) If $P_i < PET_i$ then:

$$AET_i = P_i + LS_i + LU_i = P_i + \text{Minimum}\ (SS_{i-1},\ PET_i - P_i)$$
$$+ \text{Minimum}\ (SU_{i-1},\ (PET_i - P_i - LS_i)\ SU_{i-1}/(PAW_{max} - 2.5))$$

where: LS_i and LU_i are the water losses from the surface and underlying layers in the current time period, respectively,

PET_i is the estimated potential evapotranspiration, and

PAW_{max} is the maximum possible plant available water in the total soil profile.

The runoff is zero for this case.

b) However, if $P_i > PET_i$ then:

$$AET_i = PET_i,$$

$$RO_i = P_i - AET_i - RE_i$$

where the soil water recharge (RE_i) is:

$$RE_i = \text{the minimum of } ((P_i - AET_i), (PAW_{max} - S_i))$$

The budget begins at a time when the soil moisture is at field capacity and water is lost from the upper layer first. Note that if SU_{i-1} is zero then the loss from the underlying layer (LU_i) is also zero. All units are in centimeters.

4. Crop Coefficients

Doorenbos and Pruitt (1977) defined the crop coefficient (KC) for a given crop as:

$$KC = AET_c/PET.$$

The crop coefficient relates to the evapotranspiration (AET_c) of a disease free crop grown in large fields under optimum soil water and fertility conditions achieving full production potential under the given environment. PET is the reference potential evapotranspiration as defined in previous sections. Factors affecting the value of the KC are mainly the crop characteristics, crop planting or sowing data, rate of crop development, length of growing season and climatic conditions. Thus, crop coefficients are defined for each crop development stage. Usually, the coefficients of a given crop are largest for the flowering/reproductive stage relative to other stages, for example, planting and early vegetative stages.

Some of the crop coefficients for selected crops as provided by Doorenbos and Pruitt are given in Table 3.4a. These were determined from field experiments with lysimeters. Table 3.4b shows the crop coefficients for Indonesia after being adjusted for local conditions.

The KC can be used to estimate the crop water requirement for different crops at various stages of development by:

$$\text{Crop Water Requirement (CWR)} = AETc = KC(PET)$$

The CWR for each growth stage and the growing season of a particular crop can be estimated from historic meteorological data. The CWR can be compared with rainfall and soil moisture to determine the appropriate crops and planting

Table 3.4a Crop Coefficients (kc)

CROP	Crop Development stages					Total growing period
	Initial	Crop development	Mid-season	Late season	At harvest	
Banana						
tropical	0.4 -0.5	0.7 -0.85	1.0 -1.1	0.9 -1.0	0.75-0.85	0.7 -0.8
subtropical	0.5 -0.65	0.8 -0.9	1.0 -1.2	1.0 -1.15	1.0 -1.15	0.85-0.95
Bean						
green	0.3 -0.4	0.65-0.75	0.95-1.05	0.9 -0.95	0.85-0.95	0.85-0.9
dry	0.3 -0.4	0.7 -0.8	1.05-1.2	0.65-0.75	0.25-0.3	0.7 -0.8
Cabbage	0.4 -0.5	0.7 -0.8	0.95-1.1	0.9 -1.0	0.8 -0.95	0.7 -0.8
Cotton	0.4 -0.5	0.7 -0.8	1.05-1.25	0.8 -0.9	0.65-0.7	0.8 -0.9
Grape	0.35-0.55	0.6 -0.8	0.7 -0.9	0.6 -0.8	0.55-0.7	0.55-0.75
Groundnut	0.4 -0.5	0.7 -0.8	0.95-1.1	0.75-0.85	0.55-0.6	0.75-0.8
Maize						
sweet	0.3 -0.5	0.7 -0.9	1.05-1.2	1.0 -1.15	0.95-1.1	0.8 -0.95
grain	0.3 -0.5*	0.7 -0.85*	1.05-1.2*	0.8 -0.95	0.55-0.6*	0.75-0.9*
Onion						
dry	0.4 -0.6	0.7 -0.8	0.95-1.1	0.85-0.9	0.75-0.85	0.8 -0.9
green	0.4 -0.6	0.6 -0.75	0.95-1.05	0.95-1.05	0.95-1.05	0.65-0.8
Pea, fresh	0.4 -0.5	0.7 -0.85	1.05-1.2	1.0 -1.15	0.95-1.1	0.8 -0.95
Pepper, fresh	0.3 -0.4	0.6 -0.75	0.95-1.1	0.85-1.0	0.8 -0.9	0.7 -0.8
Potato	0.4 -0.5	0.7 -0.8	1.05-1.2	0.85-0.95	0.7 -0.75	0.75-0.9
Rice	1.1 -1.15	1.1 -1.5	1.1 -1.3	0.95-1.05	0.95-1.05	1.05-1.2
Safflower	0.3 -0.4	0.7 -0.8	1.05-1.2	0.65-0.7	0.2 -0.25	0.65-0.7
Sorghum	0.3 -0.4	0.7 -0.75	1.0 -1.15	0.75-0.8	0.5 -0.55	0.75-0.85
Soybean	0.3 -0.4	0.7 -0.8	1.0 -1.15	0.7 -0.8	0.4 -0.5	0.75-0.9
Sugarbeet	0.4 -0.5	0.75-0.85	1.05-1.2	0.9 -1.0	0.6 -0.7	0.8 -0.9
Sugarcane	0.4 -0.5	0.7 -1.0	1.0 -1.3	0.75-0.8	0.5 -0.6	0.85-1.05
Sunflower	0.3 -0.4	0.7 -0.8	1.05-1.2	0.7 -0.8	0.35-0.45	0.75-0.85
Tobacco	0.3 -0.4	0.7 -0.8	1.0 -1.2	0.9 -1.0	0.75-0.85	0.85-0.95
Tomato	0.4 -0.5	0.7 -0.8	1.05-1.25	0.8 -0.95	0.6 -0.65	0.75-0.9
Water melon	0.4 -0.5	0.7 -0.8	0.95-1.05	0.8 -0.9	0.65-0.75	0.75-0.85
Wheat	0.3 -0.4	0.7 -0.8	1.05-1.2	0.65-0.75	0.2 -0.25	0.8 -0.9
Alfalfa	0.3 -0.4				1.05-1.2	0.85-1.05
Citrus						
clean weeding						0.65-0.75
no weed control						0.85-0.9
Olive						0.4 -0.6

Table 3.4b Estimated Crop Coefficients Used in Defining the Yield Moisture Index for Rice and Maize Crops in Indonesia.

		CROP COEFFICIENTS (KC)			
CROP	SEASON	Planting	Vegetative	Flowering	Maturity
Rice	First (E) Second (E)	.85	.95	1.05	-
Rice	First (L) Second (L)	.85	.95	1.05	.95
Maize	First (E) Second (E)	.65	1.05	.75	-
Maize	First (L) Second (L)	.65	.85	1.05	.75

(E) - Early Maturing Varieties

(L) - Medium to Late Maturing Varieties

dates to avoid or minimize drought vulnerability. In contrast to this type of land use study, the CWR can be used in real-time applications such as irrigation advisories during the growing season.

5. Climatic Diagrams

The climatic diagram is a useful tool for investigating the availability of moisture for crops. It is a graphical plot of decadal, monthly, weekly or even daily rainfall, soil moisture, PET, AET and other parameters such as pan evaporation. The crop coefficient could be used to adjust PET, thereby providing an estimate of the crop water requirement. The climatic diagram can be based on data for a particular season, climatic normals or both. For example, moisture supply and demand relationships can be monitored during the growing season by comparing real-time values to normal data. This can serve as an important tool for crop condition assessment. The climatic diagram can also be used for land use studies which investigate optimum planting dates, crop selection, irrigation requirements, etc.

The PET is estimated by the appropriate method and the AET is determined from the soil moisture budget.

6. Derived Agroclimatic Indices

Agricultural drought indices are defined as derived numbers or classification identifications which express the degree to which growing plants have been adversely affected by an abnormal moisture deficiency. The deficiency may result either from an unusually small moisture supply or an unusually large moisture demand. The sources of moisture supply are precipitation and water stored in the soil while the moisture depletion is caused by crop evapotranspiration to meet the CWR during the growing season. Rainfall, evapotranspiration, potential evapotranspiration and soil moisture are some of the variables that can be used for calculating these indices.

This study examines six different agroclimatic indices: Yield Moisture Index (YMI), Generalized Monsoon Index (GMI), R-Index, Soil Moisture Index (SMI), Palmer Drought Index (PDI) and the Moisture Availability Index (MAI). These are some of the indices used by the NOAA/Assessment and Information Services Center (AISC) for drought/early warning assessments. Details on each index follow.

Yield Moisture Index (YMI)

One of the primary agroclimatic indices used by AISC in the Yield Moisture Index, defined as:

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

where:

YMI_j is the Yield Moisture Index for the jth crop (e.g., maize, rice, beans, etc).

P_i is the precipitation which occurred during the ith crop stage (e.g., i=1 for planting, i=2 for vegetative, i=3 for reproductive/flowering, i=4 for maturity), and

KC_{ij} is the appropriate crop coefficient for the jth crop and ith crop stage as estimated from Table 3.4b for local conditions.

As discussed by Steyaert et al (1981) and Achutuni et al (1982), this drought index uses crop coefficients to weight rainfall during the growing season according to the relative water requirement between crop stages. For example, the crop coefficients for maize at planting and reproductive/flowering stages are about 0.35 and 1.05, respectively; water is about three times more important during flowering than at planting. Thus, the YMI is based on objectively weighted rainfall and should represent an improvement over cumulative rainfall during the growing season. This index can be calculated at the end of planting, vegetative, flowering and maturity crop stages. Usually water is

beneficial to the crop at these stages, however, caution must be exercised during the late maturity stage. If rainfall tends to adversely affect the crop during the final stages (grain drying), this stage should not be used in computing the YMI.

Generalized Monsoon Index (GMI)

The Generalized Monsoon Index was developed by Steyaert et al (1981) to assess rainfed crops which are grown during the monsoon season. In a sense, it is a generalized YMI which is defined for the southwest and northeast monsoon seasons. As most of Indonesia lies in the southern hemisphere, the directions of the southwest and northeast monsoon currents change to the southeast and northwest, respectively.

The GMI for the southeast monsoon season during April-July is defined as:

$$GMI_{SE} = .15\ P_4 + .30\ P_5 + .30\ P_6 + .25\ P_7.$$

The GMI for the northwest monsoon season during November-February is defined as:

$$GMI_{NW} = .15\ P_{11} + .30\ P_{12} + .30\ P_1 + .25\ P_2$$

where:

GMI_{SE} is the GMI for the southeast monsoon,

GMI_{NW} is the GMI for the northwest monsoon, and

P_i is the rainfall (i=1 for Jan, i=6 for June, etc.).

The index attaches most significance to rainfall occurring during the flowering/reproductive crop stages. Although these weights have been determined through objective analysis of historic data, they are not crop coefficients. The GMI is useful for assessing drought as well as flooding situations.

R-Index

The R-Index was developed by Yao (1969) and is defined as the ratio of AET to PET or:

$$R = AET/PET.$$

The index ranges from 0 to 1. Values near zero indicate extreme moisture stress while values near unity indicate no stress. The index can be used in crop condition assessments and also as a tool for land use studies. For example, Yao (1973) used the R-Index to demonstrate that groundnuts could not be grown in Tanzania due to drought vulnerability. Ravelo and Steyaert (1981) used the R-Index to estimate optimum crop calendars for Haiti and to eliminate erroneous crop calendars cited in the literature.

Soil Moisture Index

Ravelo and Decker (1979) proposed a Soil Moisture Index (SMI) defined as follows:

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

where:

PAW is the plant available soil moisture, and

PAW_{max} is the maximum plant available soil moisture.

The SMI is defined for values ranging from zero through 1. The SMI has been used by AISC as a crop condition assessment tool.

Palmer Drought Index

One method for combining precipitation and temperature as predictor variables was developed by Palmer (1965). The Palmer Drought Index (PDI) is universal in that persistently normal temperatures and precipitation produce an index of zero for all seasons and all climates. The completed analysis breaks the meteorological record into separate periods of drought, abnormally wet, or near normal conditions. Positive values of the index indicate wetter than normal conditions while negative values represent drought. Table 3.5 lists the descriptive terms which have been assigned to describe the character of the weather represented by various intervals of the index.

Table 3.5 Palmer Drought Index Classes for Wet and Dry Period

INDEX	CHARACTER OF RECENT WEATHER
> 4.00	Extremely wet
3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 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

Moisture Availability Index

The Moisture Availability Index (MAI) was developed by Hargreaves (1977) for use in land classification studies. The MAI is defined as:

$$MAI = PD/PET$$

where: PD is the dependable rainfall, and

PET is potential evapotranspiration.

Hargreaves showed that PD should be taken as the monthly rainfall amount which has a 0.75 probability level of occurrence, for example, as estimated by the gamma probability distribution. He further showed that PD is essentially equivalent to the 75th percentile which can be determined by ranking the monthly rainfall data. If time-series monthly rainfall data are not available, Hargreaves has developed statistical equations which can be used to adjust the "normal" amount to the 75th percentile estimate.

Interpretation of Indices

Indices can be computed from historic data over a 15-30 year period and then expressed in several forms: raw value, percent of normal, and percentile. The indices must be tested and evaluated to determine how each should be interpreted and the potential for use as an operational index to monitor general agricultural conditions. The threshold values for the indices can be established by using historic yield data and episodic data. The historic indices for each station can be plotted and the records of episodic data then used to identify the weather impact years and the critical values of the index associated with it; for example, "normal crops", "moderate drought impact on crops" (slightly below normal yields), "drought impact on crops" (reduced yields) and "severe drought impact on crops" (drastically reduced yields or crop failure). The index values for such years will be considered as a threshold value for each category.

Decisions should be made on which index or indices will be appropriate for an area of interest or for a particular purpose. The assessment then can be made by calculating the indices using the observed weather data, interpreting the index values in terms of similar values in the historic record and finally evaluating the results along with other information. The indices are mainly useful in assessing drought impact on agricultural crops, not the impact due to flooding or crop conditions in irrigated areas. Drought causes physiologic damage to a crop. Excessive moisture due to flooding can cause physical damage to the crop. Thus, flooding is a more complex assessment problem.

C. Application of Agroclimatic Tools

These agroclimatic tools can be used to develop agroclimatic assessment models including: 1) drought early-warning and crop condition assessments, 2) crop monitoring to determine irrigation scheduling requirements and 3) land and water resource management applications. Examples of these models and their application are provided in this report.

CHAPTER IV

ANALYTIC RESULTS

A. Overview

Four major types of agroclimatic analyses for Indonesia were performed including: 1) investigating and evaluating various methods for estimating potential evapotranspiration, 2) estimating soil moisture and calculating the Palmer Drought Index, 3) developing historic agroclimatic/crop condition indices for use in assessments and 4) developing preliminary statistical climate/crop yield models for main rice for select areas in Indonesia. The PET results are discussed in this Chapter. The agroclimatic/crop condition indices and statistical modeling results are discussed in Chapter V. The use of crop index models, statistical models, soil moisture and other assessment tools for making assessments are discussed in Chapter VI. The following summarizes the types of analysis.

1. Potential Evapotranspiration

The methods for estimating PET discussed in Chapter III were investigated using monthly data at four agrometeorological stations. The estimated PET values were compared to each other and to pan evaporation. Mean values, variances and ratios were determined as appropriate for each station. The goal was to investigate the "appropriate" method for estimating PET, to determine if PET normals can be used instead of individual monthly values, and to determine how to interpolate or estimate PET at data sparse locations.

2. Soil Moisture and the PDI

The results of the PET analysis were used to estimate moisture using the Palmer two-layer model and then to calculate the PDI. The soil moisture estimates are integral to the assessment program. The PDI shows promise as a potential index for monitoring climatic conditions at individual stations.

3. Agroclimatic/Crop Condition Indices

These indices are based on monthly rainfall data at agroclimatical stations and represent primary tools for assessing drought impact in Indonesia.

4. Statistical Models

These preliminary models require test and evaluation and should be used with caution.

B. PET Results

Comparison of the Penman, Thornthwaite and Hargreaves methods of estimating PET for Cipanas, Maros, Mojosari and Pusaka Negara are shown in Figures 4.1a-d. The monthly mean rainfall and pan evaporation are included for comparison. In general, PET estimates during the dry season are larger than those in the wet season. Also, the different PET methods tend to show the least scatter during the wet season.

Rainfall amounts in excess of PET indicate moisture surplus and vice-versa. Figures 4.1a-d show why crops are grown in the wet season and why irrigation is needed in the dry season. Rainfall is usually adequate at Cipanas but crops probably experience some drought stress at Pusaka Negara and Mojosari, particularly at the beginning of planting.

Tables 4.1a-d show the simple statistics (mean, standard deviation, etc.) for these climatic variables and PET at each station. The number of years in the data base is indicated by "N". If the standard deviation is squared, the variances between PET, pan and rainfall can be compared. In general the rainfall variance is about 10,000 mm^2 while PET and pan are about 100-400 mm^2. On an order of magnitude basis, rainfall is about 100 times more variable than either PET or pan evaporation. This suggests that for some applications, sample mean PET can be used instead of individual calculations for each month (or decade). For example, this finding could be used in soil moisture budget

INDONESIA

PET ANALYSIS

CIPANAS

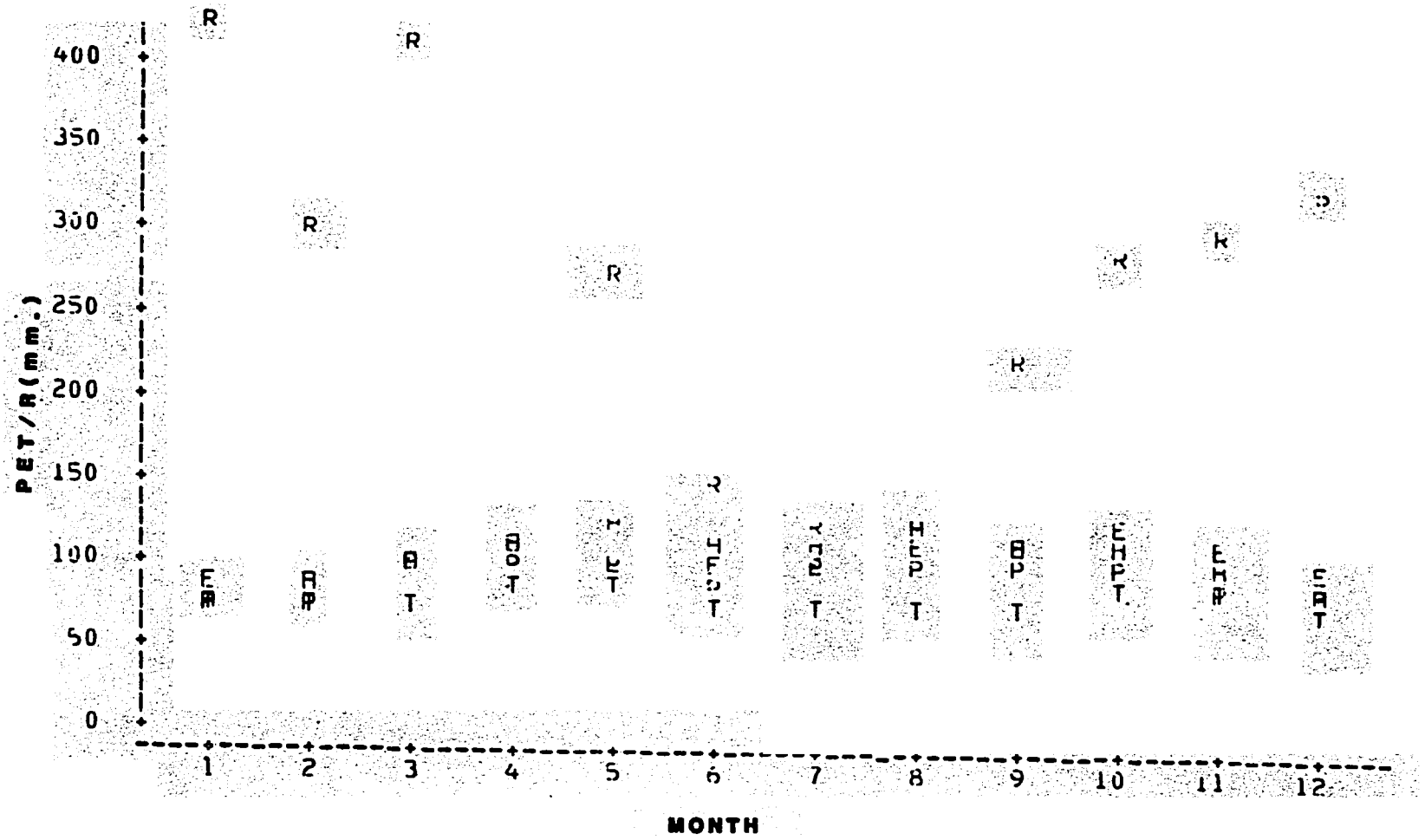


FIGURE 4.1a Potential Evapotranspiration Analysis for Cipanas (P=Penman, T=Thornthwaite, H=Hargreaves, E=Pan Evaporation and R=Rainfall).

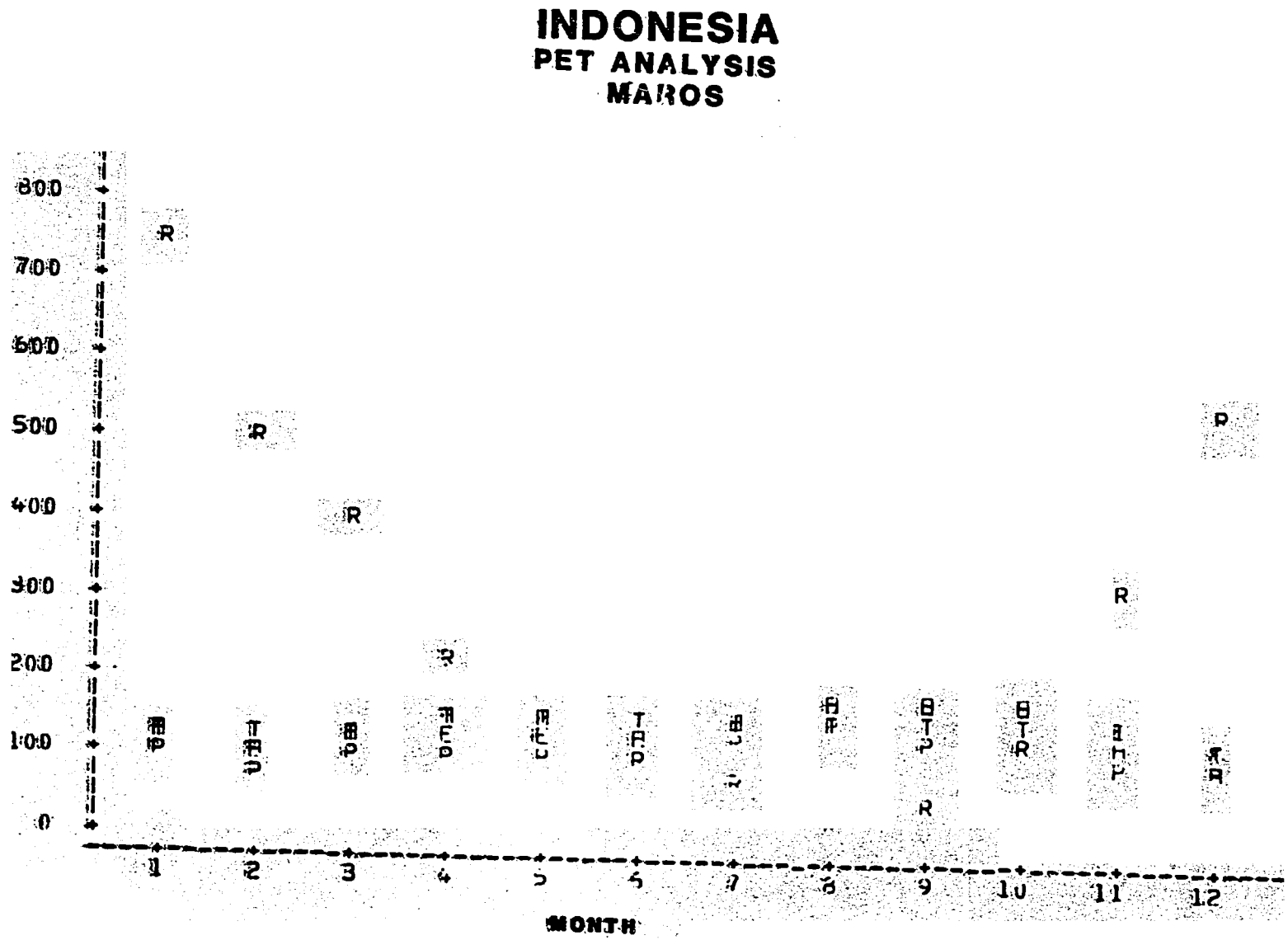


FIGURE 4.1b Potential Evapotranspiration Analysis for Maros (P=Penman, T=Thornthwaite, H=Hargreaves, E=Pan Evaporation and R=Rainfall).

INDONESIA

PET ANALYSIS

MOJOSARI

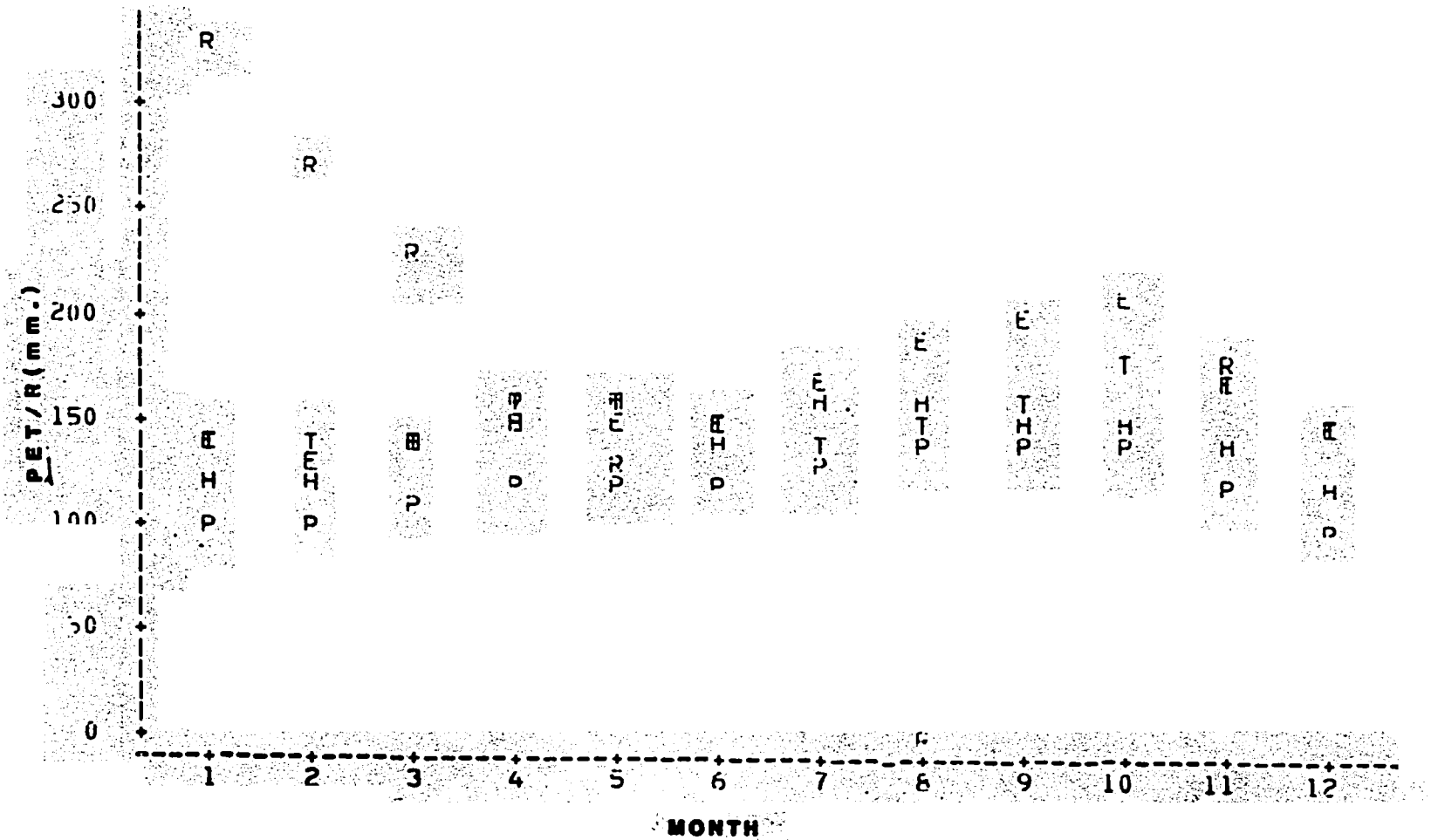


FIGURE 4.1c Potential Evapotranspiration Analysis for Mojosari (P=Penman, T=Thornthwaite, H=Hargreaves, E=Pan Evaporation and R=Rainfall)

INDONESIA

PET ANALYSIS

PUSAKA NEGARA

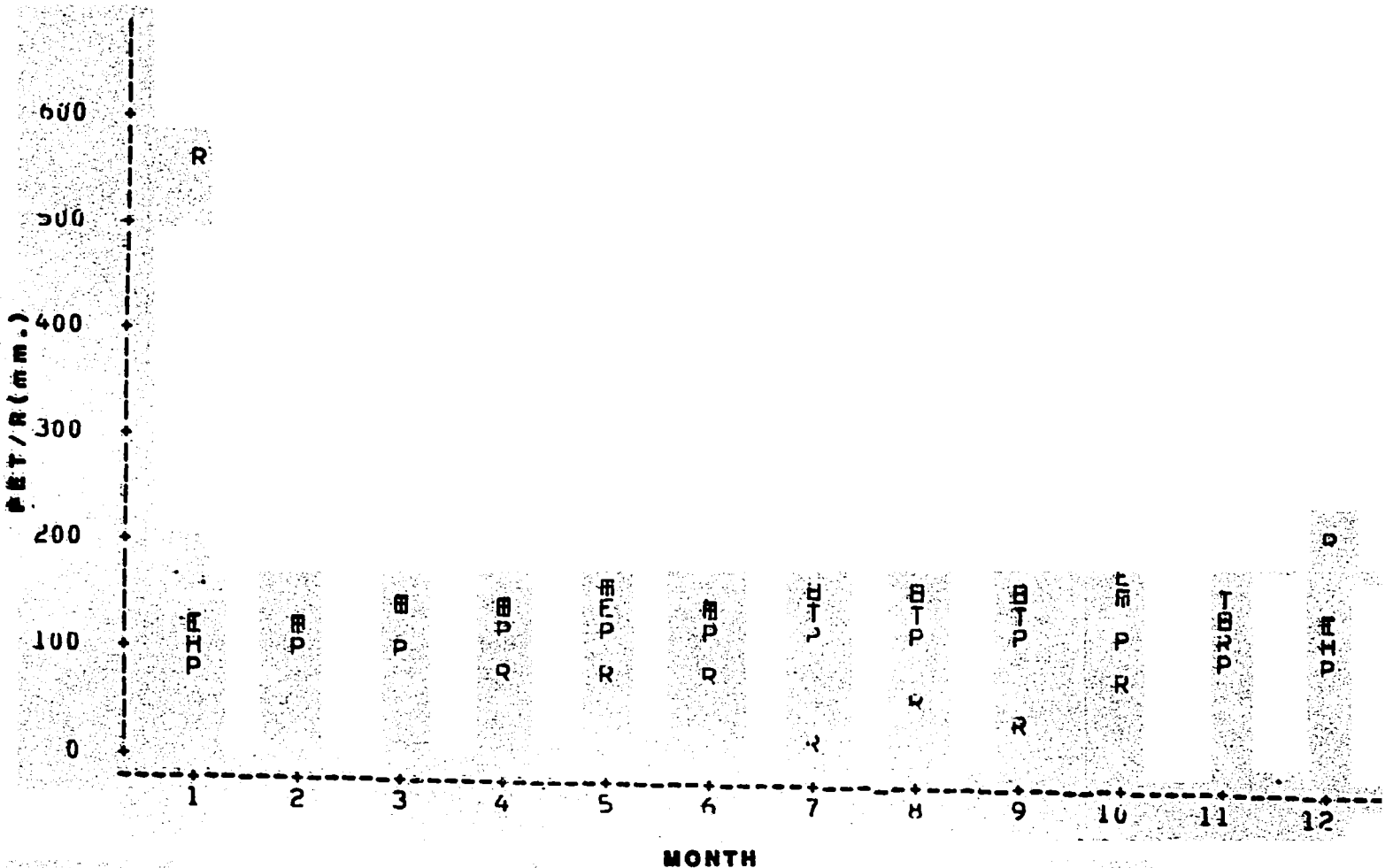


FIGURE 4.1d Potential Evapotranspiration Analysis for Pusaka Negara (P=Penman, T=Thornthwaite, H=Hargreaves, E=Pan Evaporation and R=Rainfall).

INDONESIA
PET, PAN EVAPORATION AND RAINFALL STATISTICS
CIPANAS

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
P1	9	430.1	143.5	164.0	615.0	20605.4
P2	9	294.1	96.1	158.0	495.0	9225.6
P3	9	414.9	146.7	295.0	753.0	21524.6
P4	9	313.9	62.3	204.0	397.0	3877.6
P5	9	276.0	107.5	151.0	493.0	11553.8
P6	9	155.8	78.4	40.0	288.0	6149.7
P7	9	129.8	95.6	17.0	317.0	9137.9
P8	9	131.3	77.9	39.0	273.0	6062.2
P9	9	229.8	118.8	57.0	417.0	14106.4
P10	9	286.9	112.1	28.0	410.0	12556.1
P11	9	300.4	72.4	172.0	375.0	5238.2
P12	9	328.6	74.3	214.0	445.0	5516.2
E1	9	83.4	11.8	68.2	102.3	140.4
E2	9	84.3	6.2	78.4	95.2	38.1
E3	9	103.7	15.0	80.6	124.0	226.1
E4	9	113.3	20.3	95.0	159.0	413.5
E5	9	105.1	13.2	93.0	127.1	174.0
E6	9	94.7	13.7	72.0	111.0	187.0
E7	9	102.3	5.8	93.0	111.6	33.6
E8	9	115.9	6.6	108.5	130.2	43.1
E9	9	112.9	8.9	96.0	125.0	78.6
E10	9	126.7	18.7	102.3	155.1	349.4
E11	9	108.7	15.6	75.0	132.0	244.7
E12	9	98.0	10.2	77.5	105.5	103.2
THORT1	9	71.4	6.1	59.9	78.6	37.5
THORT2	9	74.9	5.9	64.5	82.1	34.5
THORT3	9	78.6	5.9	67.7	84.8	35.1
THORT4	9	85.1	4.9	78.6	95.2	23.9
THORT5	9	85.2	4.4	78.5	93.2	19.0
THORT6	9	79.5	4.2	70.9	84.8	17.4
THORT7	9	77.5	2.9	74.2	83.0	8.2
THORT8	9	79.2	1.5	76.8	82.1	2.3
THORT9	9	80.6	2.7	75.8	85.7	7.5
THORT10	9	84.2	5.6	74.3	93.3	31.0
THORT11	9	82.7	3.1	76.0	85.7	9.3
THORT12	9	78.3	3.1	71.0	81.3	9.6
PENMAN1	9	80.9	6.1	69.0	87.2	36.6
PENMAN2	9	78.7	6.7	62.9	85.7	45.0
PENMAN3	9	95.5	7.9	82.8	105.9	62.1
PENMAN4	9	95.2	3.9	89.7	101.3	15.3
PENMAN5	9	97.3	5.0	91.4	106.1	24.9
PENMAN6	9	91.6	6.0	83.5	101.2	35.7

TABLE 4.1a PET, Pan Evaporation and Rainfall Statistics for Cipanas.

INDONESIA

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
PENMAN7	9	99.0	4.1	90.5	104.7	17.2
PENMAN8	9	100.6	2.3	96.3	104.1	5.5
PENMAN9	9	95.4	4.6	89.1	105.3	21.0
PENMAN10	9	99.0	8.9	84.6	116.1	79.8
PENMAN11	9	88.0	5.1	79.1	97.6	26.4
PENMAN12	9	83.2	3.3	77.0	88.1	10.9
HARGRS1	9	76.9	5.1	68.5	83.6	26.4
HARGRS2	9	81.5	6.9	64.2	87.3	48.3
HARGRS3	9	104.7	10.6	90.3	121.0	112.0
HARGRS4	9	112.5	4.2	107.9	120.0	17.2
HARGRS5	9	119.3	7.5	110.0	132.8	57.0
HARGRS6	9	111.5	9.7	96.0	125.8	94.1
HARGRS7	9	118.5	5.7	107.1	129.2	32.2
HARGRS8	9	124.7	4.8	118.7	128.0	25.2
HARGRS9	9	113.1	6.1	104.6	124.6	37.8
HARGRS10	9	115.7	11.6	95.5	135.9	134.2
HARGRS11	9	98.7	6.3	88.5	109.6	39.1
HARGRS12	9	86.3	4.3	80.8	95.5	18.2

TABLE 4.1a PET, Pan Evaporation and Rainfall Statistics for Cipanas (continued).

INDONESIA
PET,PAN EVAPORATION AND RAINFALL STATISTICS
MAROS

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
P1	7	746.5	202.4	493.0	1121.0	40955.6
P2	7	506.5	124.5	292.0	654.0	15497.3
P3	7	390.7	84.0	273.0	520.0	7057.6
P4	7	231.1	188.3	13.0	512.0	35445.1
P5	7	137.7	66.2	48.0	251.0	4384.6
P6	7	104.1	71.7	12.0	207.0	5141.8
P7	7	80.7	100.1	1.0	245.0	10022.9
P8	7	25.0	34.8	0.0	85.0	1208.7
P9	7	38.7	63.4	0.0	174.0	4021.9
P10	7	131.5	103.3	0.0	325.0	10679.3
P11	7	329.3	144.2	197.0	621.0	20782.2
P12	7	555.8	99.0	381.0	652.0	9801.1
E1	7	128.3	8.9	117.8	145.7	78.8
E2	7	112.5	16.2	86.8	137.2	262.4
E3	7	136.9	21.1	105.4	173.6	443.4
E4	7	133.3	23.9	90.0	171.0	569.5
E5	7	133.3	19.4	105.4	164.3	378.0
E6	7	126.9	17.5	99.0	153.0	305.1
E7	7	151.9	26.1	117.8	185.0	682.3
E8	7	186.0	21.5	155.0	223.2	461.3
E9	7	187.0	31.4	125.0	225.0	983.0
E10	7	174.6	37.3	117.8	241.8	1392.4
E11	7	154.0	23.1	125.0	185.0	533.0
E12	7	128.1	15.0	108.5	145.7	226.4
THORT1	7	133.3	8.2	122.3	141.9	67.1
THORT2	7	132.0	9.1	118.6	143.9	82.1
THORT3	7	134.7	10.7	116.7	145.0	113.7
THORT4	7	146.0	5.6	137.7	154.6	31.4
THORT5	7	154.7	5.5	143.8	161.3	30.1
THORT6	7	149.8	8.8	133.6	159.0	77.2
THORT7	7	144.6	8.0	133.7	154.6	63.7
THORT8	7	148.2	6.5	137.7	155.8	42.4
THORT9	7	153.0	8.1	141.8	163.7	65.9
THORT10	7	155.3	11.9	135.7	175.5	142.6
THORT11	7	149.9	11.6	131.8	165.4	134.4
THORT12	7	135.6	8.2	126.0	145.1	68.0
PENMAN1	7	93.8	3.0	87.5	95.6	9.0
PENMAN2	7	86.6	4.0	78.9	90.3	15.7
PENMAN3	7	100.6	2.1	97.6	103.7	4.4
PENMAN4	7	109.8	1.4	107.6	112.3	2.1
PENMAN5	7	110.5	2.0	106.8	112.6	3.9
PENMAN6	7	106.7	3.1	100.7	110.6	9.4

TABLE 4.1b PET, Pan Evaporation and Rainfall Statistics for Maros.

INDONESIA

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
PENMAN7	7	122.4	7.1	112.7	130.3	50.3
PENMAN8	7	142.5	5.6	133.7	149.1	31.3
PENMAN9	7	131.6	8.9	115.7	145.1	79.4
PENMAN10	7	128.8	11.8	111.1	151.4	139.5
PENMAN11	7	107.4	7.4	96.8	121.4	54.4
PENMAN12	7	90.5	2.3	88.4	94.8	5.4
HARGRS1	7	114.8	4.2	105.7	118.8	17.8
HARGRS2	7	104.0	5.9	92.5	112.3	34.3
HARGRS3	7	128.8	1.8	126.0	130.7	3.3
HARGRS4	7	152.7	1.7	149.5	154.6	3.0
HARGRS5	7	152.7	3.0	146.8	155.9	8.9
HARGRS6	7	132.4	5.8	120.0	138.1	33.3
HARGRS7	7	152.7	7.8	141.4	161.7	61.2
HARGRS8	7	174.1	7.8	159.1	184.2	61.4
HARGRS9	7	162.9	10.2	145.3	180.6	104.8
HARGRS10	7	166.0	15.2	142.3	193.3	230.8
HARGRS11	7	137.3	9.2	123.4	154.8	85.2
HARGRS12	7	112.2	5.9	104.2	123.5	35.1

TABLE 4.1b PET, Pan Evaporation and Rainfall Statistics for Maros (continued).

INDONESIA
PET,PAN EVAPORATION AND RAINFALL STATISTICS
MOJOSARI

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
P1	9	330.2	76.7	238.0	451.0	5887.7
P2	9	265.2	56.4	178.0	350.0	3178.2
P3	9	233.7	140.5	92.0	463.0	19751.5
P4	9	158.7	97.8	45.0	373.0	9568.4
P5	9	131.7	101.5	7.0	271.0	10304.0
P6	9	27.9	25.7	0.0	63.0	660.4
P7	9	7.1	8.9	0.0	27.0	79.6
P8	9	4.9	8.8	0.0	27.0	78.1
P9	9	42.5	50.6	0.0	134.0	2563.0
P10	9	34.0	42.0	0.0	113.0	1766.5
P11	9	177.8	101.2	69.0	388.0	10237.4
P12	9	259.5	97.0	116.0	421.0	9413.0
E1	9	136.4	25.0	108.5	173.6	624.7
E2	9	131.6	26.3	95.2	163.2	689.9
E3	9	142.6	27.5	99.2	173.6	756.8
E4	9	153.0	19.4	111.0	177.0	378.0
E5	9	152.6	27.6	105.4	179.8	761.1
E6	9	149.0	18.9	123.0	177.0	357.8
E7	9	169.3	16.8	142.6	192.2	280.9
E8	9	188.7	17.1	167.4	213.9	291.8
E9	9	196.1	19.8	168.0	219.0	393.6
E10	9	209.2	39.6	139.5	263.5	1566.4
E11	9	171.7	47.0	102.0	243.0	2213.4
E12	9	150.3	21.5	127.1	185.0	461.3
THORT1	9	139.7	14.1	117.0	158.8	199.0
THORT2	9	140.6	13.1	120.7	163.5	170.5
THORT3	9	143.0	10.5	132.5	163.9	111.2
THORT4	9	158.0	11.7	136.6	173.2	135.9
THORT5	9	159.5	13.4	142.9	185.0	180.3
THORT6	9	152.1	12.3	140.8	180.8	150.6
THORT7	9	142.0	13.8	122.5	163.4	190.2
THORT8	9	146.8	11.8	130.4	165.2	139.4
THORT9	9	159.5	15.7	143.0	194.1	245.5
THORT10	9	177.6	20.7	149.6	219.9	430.5
THORT11	9	170.1	26.7	138.8	223.0	713.3
THORT12	9	150.8	16.7	130.5	175.9	278.1
PENMAN1	9	99.8	6.2	94.1	111.7	38.3
PENMAN2	9	98.3	5.6	89.8	105.8	31.4
PENMAN3	9	111.7	6.1	104.4	121.8	37.4
PENMAN4	9	121.8	11.8	96.0	133.0	139.6
PENMAN5	9	124.8	14.9	97.0	145.9	221.4
PENMAN6	9	118.8	14.5	92.1	143.7	210.3

TABLE 4.1c PET, Pan Evaporation and Rainfall Statistics for Mojosari.

INDONESIA

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
PENMAN7	9	129.2	11.2	114.2	145.6	125.4
PENMAN8	9	139.6	15.1	107.7	159.6	228.4
PENMAN9	9	136.0	16.4	99.9	153.4	268.6
PENMAN10	9	137.4	18.1	110.7	172.5	327.0
PENMAN11	9	117.4	14.6	95.1	141.6	213.4
PENMAN12	9	98.5	7.6	86.6	113.0	57.6
HARGRS1	9	120.8	10.4	103.8	134.5	108.9
HARGRS2	9	122.8	8.8	106.7	135.6	76.6
HARGRS3	9	139.6	9.4	126.6	157.9	89.1
HARGRS4	9	152.4	14.8	117.6	163.6	218.3
HARGRS5	9	157.2	17.5	120.1	181.4	307.6
HARGRS6	9	144.9	20.2	94.9	165.6	409.0
HARGRS7	9	156.6	13.5	137.4	174.0	183.4
HARGRS8	9	163.1	20.8	111.0	182.2	433.2
HARGRS9	9	153.6	20.8	104.8	175.3	432.8
HARGRS10	9	154.2	19.6	118.9	181.9	385.8
HARGRS11	9	138.1	10.1	119.5	153.5	102.7
HARGRS12	9	119.8	10.3	101.0	14[illegible]	106.2

TABLE 4.1c PET, Pan Evaporation and Rainfall Statistics for Mojosari (continued).

INDONESIA
PET, PAN EVAPORATION AND RAINFALL STATISTICS
PUSAKA NEGARA

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
P1	9	558.7	295.3	183.0	975.0	87225.0
P2	9	311.2	198.5	77.0	758.0	39387.2
P3	9	264.0	142.1	96.0	521.0	20187.3
P4	9	82.6	47.5	35.0	167.0	2253.5
P5	9	78.1	51.9	1.0	139.0	2697.4
P6	9	77.1	54.9	7.0	139.0	3008.9
P7	9	28.4	31.5	0.0	95.0	994.5
P8	9	62.3	68.6	0.0	185.0	4699.4
P9	9	42.0	35.4	0.0	105.0	1256.5
P10	9	70.1	37.5	30.0	137.0	1406.1
P11	9	117.8	68.8	14.0	252.0	4727.7
P12	9	227.1	109.1	91.0	435.0	11900.6
E1	9	119.2	12.3	99.2	133.3	151.6
E2	9	123.8	15.0	100.8	142.8	225.0
E3	9	140.5	15.0	120.9	161.2	225.8
E4	9	138.3	12.1	117.0	155.0	147.3
E5	9	138.8	23.3	105.4	173.6	542.4
E6	9	134.7	24.6	102.0	165.0	606.3
E7	9	153.1	24.2	114.7	182.9	583.7
E8	9	163.5	17.0	135.4	182.9	287.7
E9	9	167.6	22.4	126.0	198.0	502.7
E10	9	175.1	34.7	117.8	248.0	1203.7
E11	9	149.2	27.9	111.0	207.0	780.2
E12	9	143.8	15.8	120.9	164.3	249.7
THORT1	9	123.8	13.9	106.1	144.5	193.2
THORT2	9	127.8	9.8	117.9	150.7	96.4
THORT3	9	131.8	6.3	125.1	145.5	39.2
THORT4	9	147.0	5.9	138.4	157.0	34.3
THORT5	9	151.4	6.3	142.3	165.9	40.3
THORT6	9	140.9	6.7	128.7	152.7	45.5
THORT7	9	130.7	5.0	123.2	135.4	24.8
THORT8	9	130.0	6.4	121.4	135.4	40.6
THORT9	9	142.0	8.0	132.6	161.5	63.3
THORT10	9	153.8	8.9	144.5	172.9	78.4
THORT11	9	152.0	10.3	144.5	177.6	106.0
THORT12	9	136.9	7.9	127.0	150.7	62.4
PENMAN1	9	89.8	7.5	75.1	102.5	56.9
PENMAN2	9	91.7	6.4	80.0	100.6	40.9
PENMAN3	9	109.5	4.7	100.9	115.5	22.3
PENMAN4	9	111.0	4.2	105.8	117.1	17.7
PENMAN5	9	120.9	7.7	111.4	134.1	59.5
PENMAN6	9	113.6	10.9	94.4	133.3	118.2

TABLE 4.1d PET, Pan Evaporation and Rainfall Statistics for Pusaka Negara.

INDONESIA

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	VARIANCE
PENMAN7	9	123.2	12.8	105.5	145.5	162.6
PENMAN8	9	127.0	8.5	111.4	135.2	71.6
PENMAN9	9	125.8	11.4	109.3	141.7	129.7
PENMAN10	9	126.1	13.2	107.6	155.7	173.1
PENMAN11	9	107.0	8.9	98.9	129.2	78.5
PENMAN12	9	96.0	6.1	88.7	105.9	37.1
HARGRS1	9	102.3	9.6	86.0	115.7	91.3
HARGRS2	9	113.9	10.1	90.8	128.5	102.2
HARGRS3	9	143.1	9.2	127.5	159.4	84.2
HARGRS4	9	145.4	6.7	137.6	155.0	45.3
HARGRS5	9	155.3	7.8	146.3	165.0	60.2
HARGRS6	9	143.6	11.9	119.0	164.0	140.7
HARGRS7	9	157.5	11.8	138.3	173.6	138.2
HARGRS8	9	162.7	8.2	146.8	175.0	68.0
HARGRS9	9	155.8	12.5	135.9	173.7	157.3
HARGRS10	9	157.0	12.5	133.7	183.1	156.7
HARGRS11	9	130.5	7.2	122.7	147.3	52.2
HARGRS12	9	114.3	6.2	102.2	125.6	38.5

TABLE 4.1d (continued) PET, Pan Evaporation and Rainfall Statistics for Pusaka Negara.

analysis or in crop water requirement calculations using crop coefficients.

Figures 4.2a-c and 4.3a-b demonstrate more characteristics of PET variability. Figures 4.2a-c show the individual monthly climatic variables during 1973-1981 for January, June and September at Cipanas, respectively. The time-series for June and September have greater scatter than during January (even though the scales are different). Large amounts of rainfall during January probably dampens variability of the other parameters. In Figures 4.3a-b, the mean and standard deviations for Penman PET at Cipanas and Pusaka Negara are shown. In Cipanas the smallest standard deviation is found at the end of the dry season while in Pusaka Negara the smallest standard deviations are found during the wet season.

Table 4.2 shows the ratios of Penman, Hargreaves and Thornthwaite PET to pan evaporation and 80 percent of pan evaporation for Cipanas, Moros, Mojosari and Pusaka Negara. Sample plots for Cipanas are shown in Figures 4.4a-b. These ratios suggest how the methods can be adjusted if pan is used as a reference criteria. In this case, 80 percent of pan evaporation is used as the simplest PET model. In general, Penman and Hargreaves' PET estimates are below pan values. However, Thornthwaite PET estimates are frequently greater except in high elevation stations (i.e. Cipanas). The Thornthwaite estimated PET values are well above pan during the wet season and well below pan during the dry season. Penman and Hargreaves PET compare favorably with 80 percent of pan evaporation; however, there are some local differences.

Some comments are to be noted before suggesting the findings. The large variability of PET during the wet or dry season as compared to PET variability during the rest of the year seems to be associated with temperature variability. For example, during the rainy season in Pusaka Negara, station mean temperatures vary by about 1-2°C from year-to-year, but as much as 3-4°C during the wet

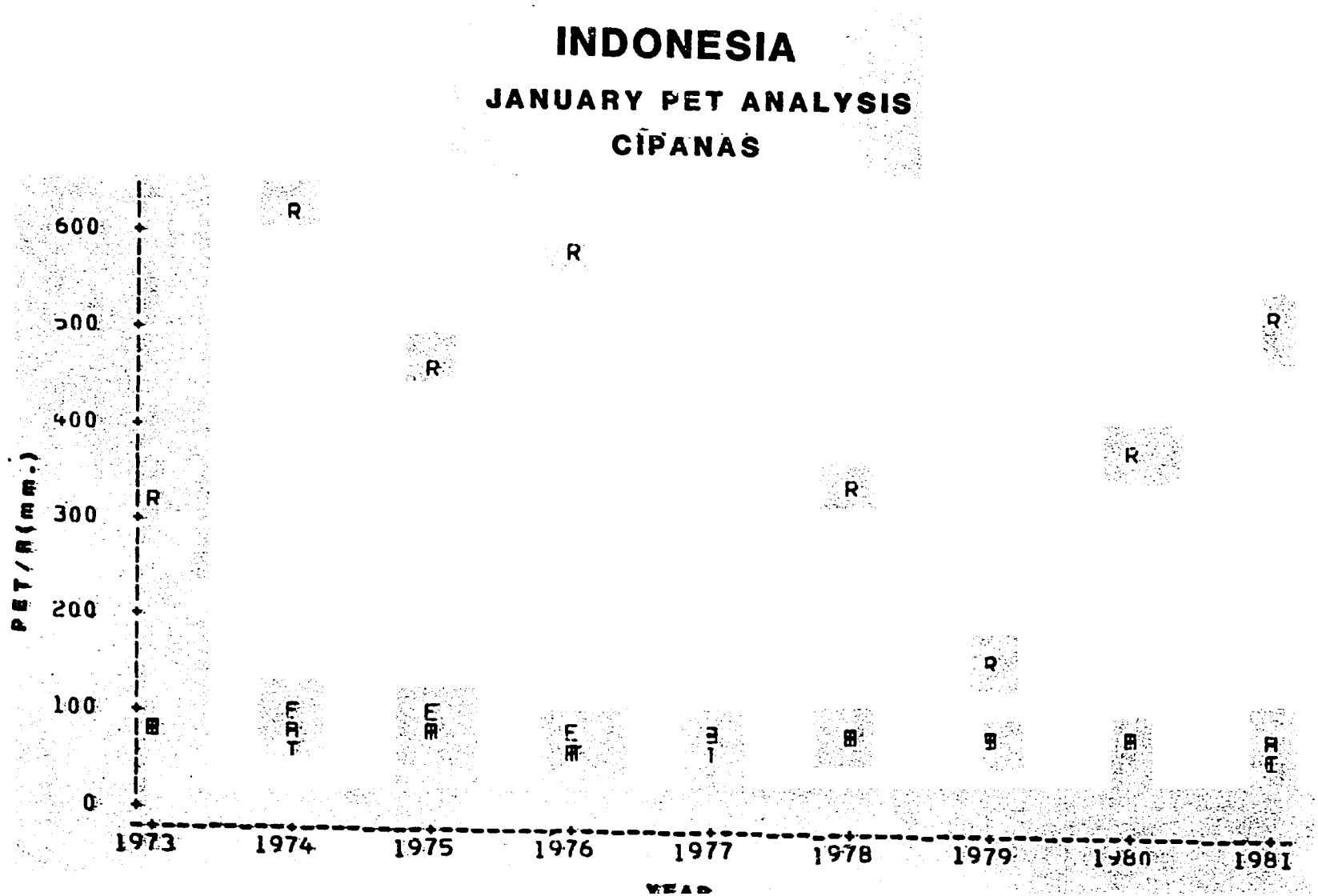


FIGURE 4.2a Comparison of Historical Potential Evapotranspiration Estimates for January by the Penman (P), Thornthwaite (T) and Hargreaves (H) Methods at Cipanas. Monthly Rainfall (R) and Pan Evaporation (E) Values are also Indicated.

INDONESIA

JUNE PET ANALYSIS

CIPANAS

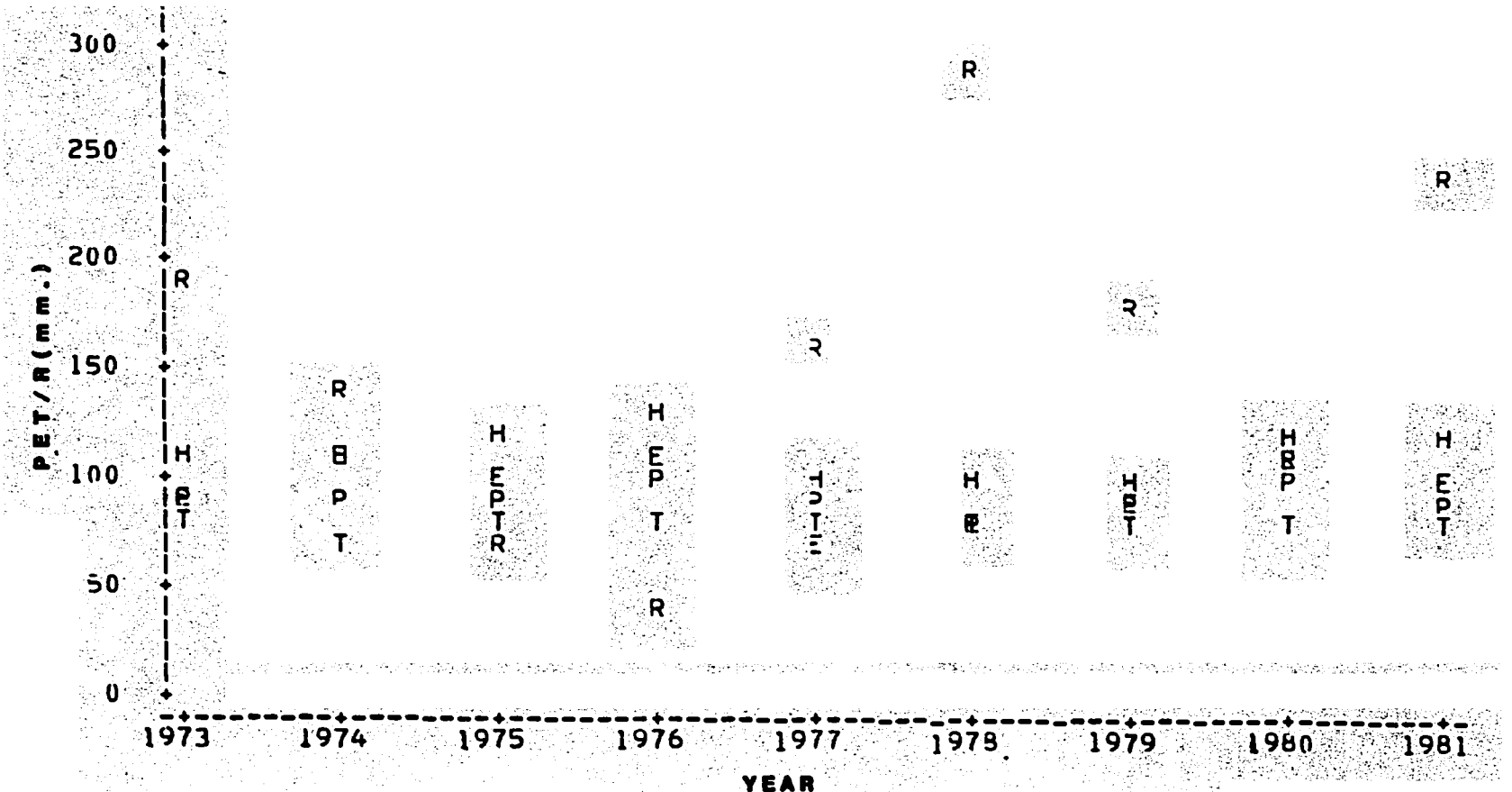


FIGURE 4.2b Comparison of Historical Potential Evapotranspiration Estimates for June by the Penman (P), Thornthwaite (T) and Hargreaves (H). Methods at Cipanas. Monthly Rainfall (R) and Pan Evaporation (E) Values are also Indicated.

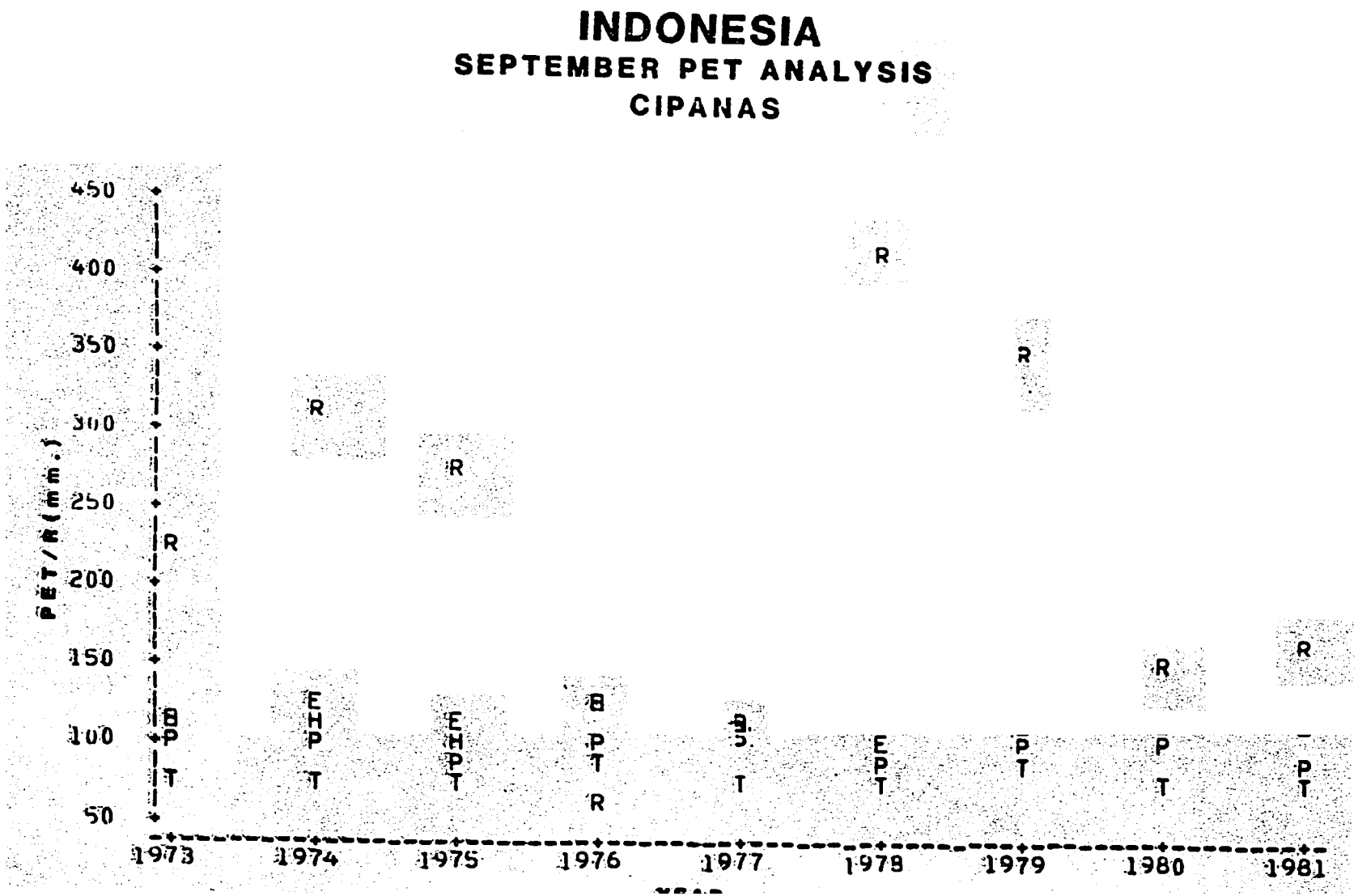


FIGURE 4.2c Comparison of Historical Potential Evapotranspiration Estimates for September by the Penman (P), Thornthwaite (T), and Hargreaves (H) Methods at Cipanas. Monthly Rainfall (R) and Pan Evaporation (E) Values are also Indicated.

INDONESIA

MEAN PENMAN PET AND STANDARD DEVIATIONS

CIPANAS

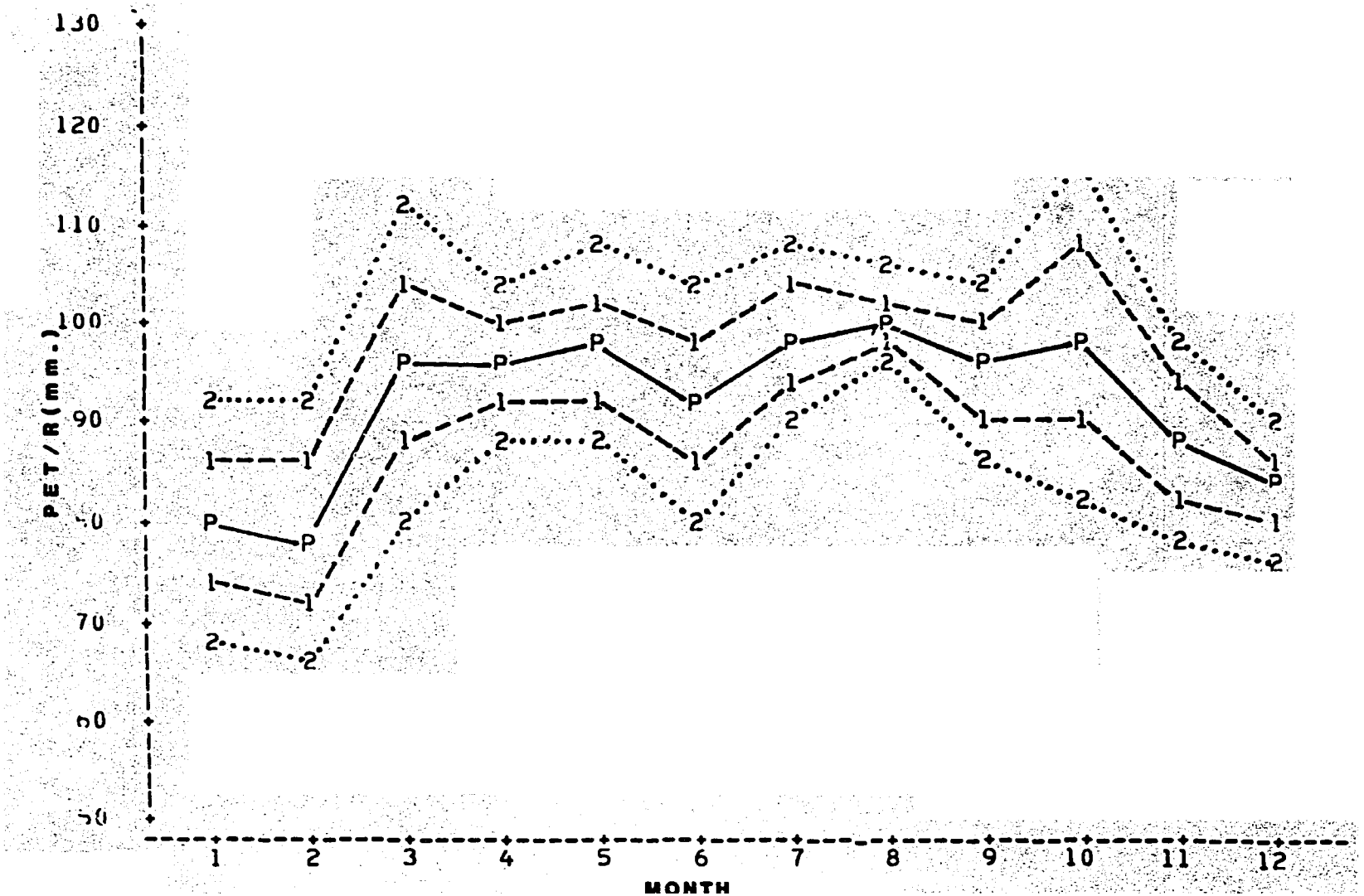


FIGURE 4.3a Mean Monthly Penman Potential Evapotranspiration Values for Cipanas Showing the 1 and 2 Standard Deviation Limits.

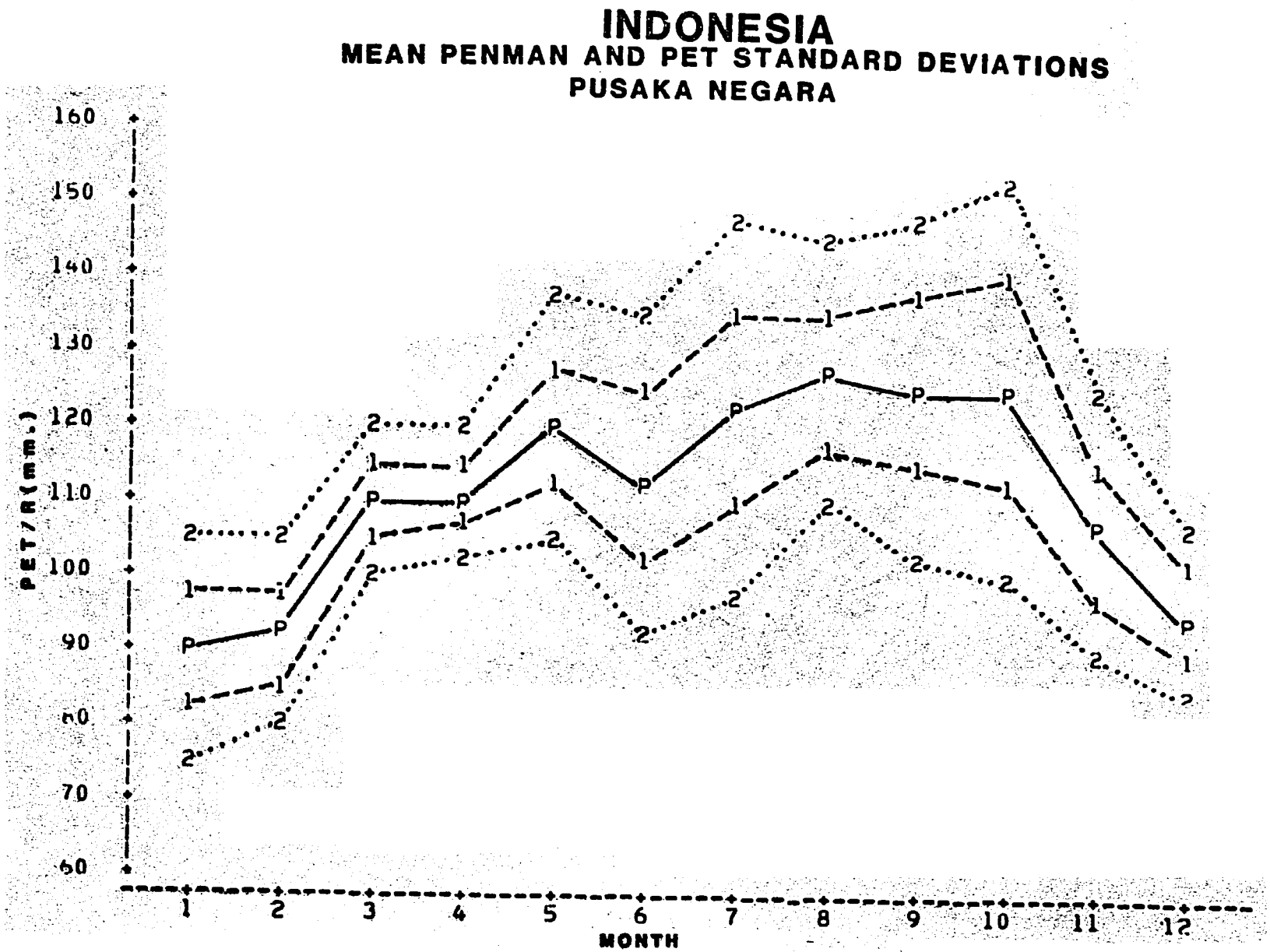


FIGURE 4.3b Mean Monthly Penman Potential Evapotranspiration Values for Pusaka Negara Showing the 1 and 2 Standard Deviation Limits.

INDONESIA
PET RATIOS
CIPANAS AND MAROS

NAME=CIPANAS

OBS	MON	RP_E	RP_8E	RH_E	RH_8E	RT_E	RT_8E
1	1	0.970358	1.21295	0.92298	1.15372	0.856266	1.07033
2	2	0.933452	1.16707	0.96534	1.20793	0.888170	1.11021
3	3	0.921416	1.15177	1.00975	1.26218	0.758067	0.94758
4	4	0.839955	1.04982	0.99265	1.24082	0.750730	0.93841
5	5	0.925939	1.15742	1.13512	1.41890	0.810539	1.01317
6	6	0.968071	1.21009	1.17733	1.47166	0.839372	1.04921
7	7	0.967280	1.20910	1.15558	1.44823	0.757288	0.94661
8	8	0.868282	1.08535	1.07508	1.34510	0.683417	0.85427
9	9	0.844996	1.05625	1.00234	1.25292	0.713857	0.89232
10	10	0.780980	0.97622	0.91335	1.14168	0.664103	0.83013
11	11	0.809311	1.01164	0.90782	1.13478	0.760580	0.95110
12	12	0.849083	1.06135	0.88069	1.10087	0.798586	0.99861

NAME=MAROS

OBS	MON	RP_E	RP_8E	RH_E	RH_8E	RT_E	RT_8E
25	1	0.731017	0.91377	0.89415	1.11769	1.03834	1.29792
26	2	0.769954	0.96244	0.92494	1.15618	1.17337	1.46672
27	3	0.734740	0.91842	0.94060	1.17575	0.98345	1.22931
28	4	0.823806	1.02976	1.14585	1.43232	1.09558	1.36960
29	5	0.828759	1.03595	1.14567	1.43209	1.16021	1.45026
30	6	0.841039	1.05130	1.04394	1.30493	1.18057	1.47572
31	7	0.805615	1.00702	1.00542	1.25677	0.95150	1.18975
32	8	0.766133	0.95767	0.93507	1.17009	0.79659	0.99586
33	9	0.703659	0.879824	0.870852	1.08858	0.81792	1.02240
34	10	0.737362	0.921703	0.950472	1.18809	0.88952	1.11189
35	11	0.697410	0.871763	0.891847	1.11481	0.97335	1.21669
36	12	0.706081	0.882602	0.875850	1.09481	1.05512	1.32265

TABLE 4.2 PET Ratios for Cipanas and Maros (RP_E=P/E, RP_8E=P/.8E, RH_E=H/E, RH_8E=H/.8E, RT_E=T/E and RT_8E=T/.8E).

INDONESIA
PET RATIOS
MOJOSARI AND PUSAKA NEGARA

NAME=MOJOSARI

OBS	MON	RP_E	RP_8E	RH_E	RH_8E	RT_E	RT_8E
37	1	0.731451	0.91431	0.88351	1.10689	1.02434	1.28068
38	2	0.747028	0.93378	0.93341	1.16676	1.06823	1.33529
39	3	0.783551	0.97944	0.97905	1.22383	1.00295	1.25357
40	4	0.796201	0.99525	0.99524	1.24530	1.03236	1.29045
41	5	0.817567	1.02196	1.03049	1.28811	1.04558	1.30697
42	6	0.797179	0.99647	0.97233	1.21541	1.02048	1.27561
43	7	0.762874	0.95359	0.92502	1.15628	0.83859	1.04823
44	8	0.739516	0.92440	0.86408	1.08010	0.77791	0.97238
45	9	0.693243	0.86655	0.78312	0.97890	0.81333	1.01667
46	10	0.656394	0.82049	0.73713	0.92141	0.84852	1.06065
47	11	0.683372	0.85421	0.80428	1.00535	0.99015	1.23768
48	12	0.655055	0.81882	0.79585	0.99606	1.00329	1.25411

NAME=PUSAKA NEGARA

OBS	MON	RP_E	RP_8E	RH_E	RH_8E	RT_E	RT_8E
49	1	0.753203	0.94150	0.85823	1.07278	1.03890	1.29863
50	2	0.740701	0.92588	0.91981	1.14976	1.03220	1.29025
51	3	0.779059	0.97382	1.01825	1.27282	0.93802	1.17252
52	4	0.802440	1.00305	1.05133	1.31417	1.06257	1.32821
53	5	0.871074	1.08884	1.11901	1.39876	1.09052	1.36315
54	6	0.843540	1.05442	1.06535	1.33296	1.04610	1.30763
55	7	0.804909	1.00601	1.02929	1.28661	0.85371	1.06713
56	8	0.776482	0.97060	0.99488	1.24335	0.79515	0.99394
57	9	0.750489	0.93811	0.92939	1.15174	0.84738	1.05922
58	10	0.719711	0.89964	0.89565	1.12082	0.87793	1.09741
59	11	0.717174	0.89647	0.87418	1.09273	1.01837	1.27297
60	12	0.667663	0.83458	0.79511	0.99388	0.95233	1.19041

TABLE 4.2 PET Ratios for Mojosari and Pusaka Negara (RP_E=P/E, RP_8E=P/.8E, RH_E=H/E, RH_8E=H/.8E, RT_E=T/E and RT_8E=T/.8E) (continued).

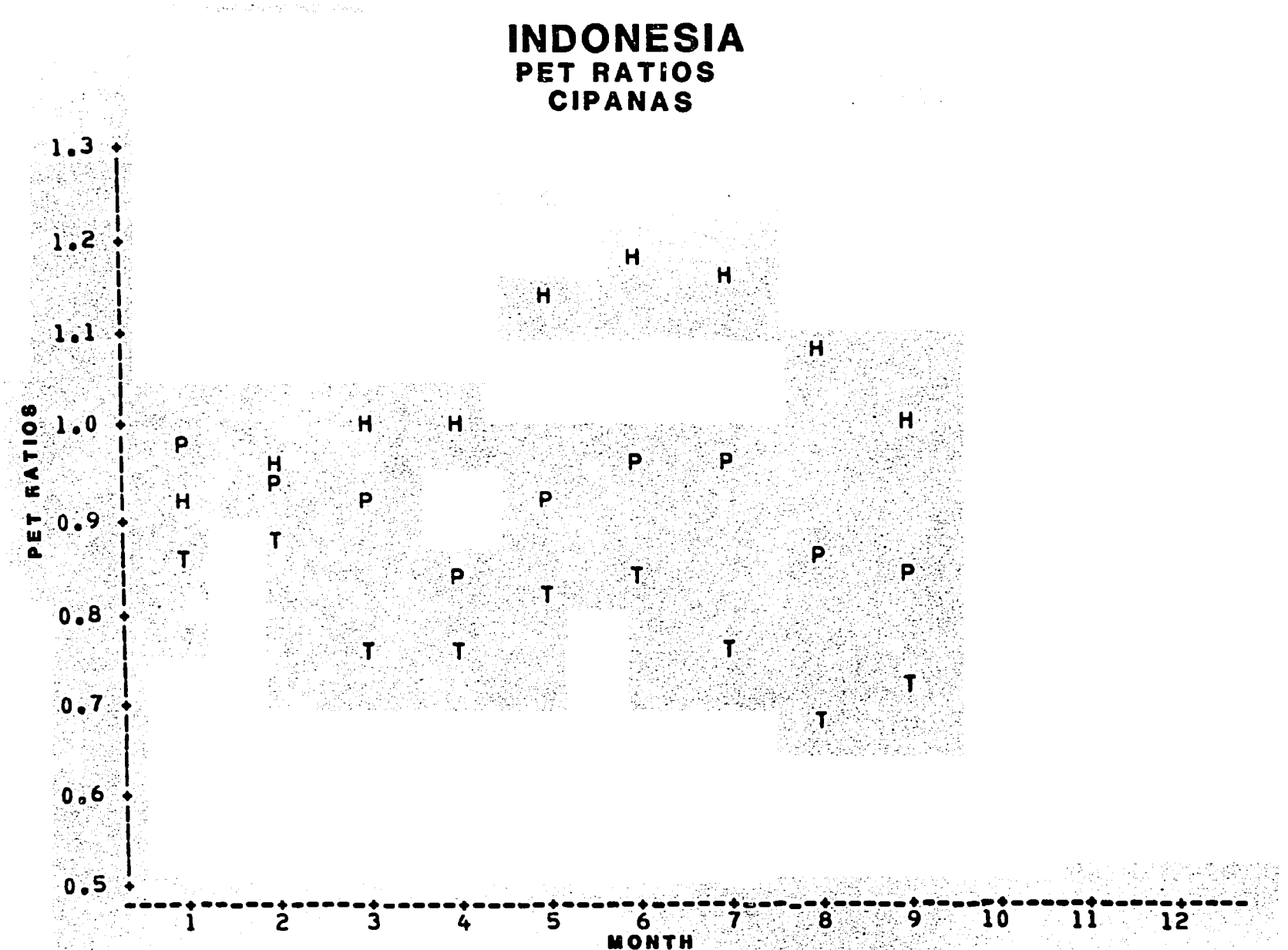


FIGURE 4.4a Comparison of Mean Monthly PET Ratios (P=Penman/Pan, H=Hargreaves/Pan and T=Thornthwaite/Pan) for Cipanas.

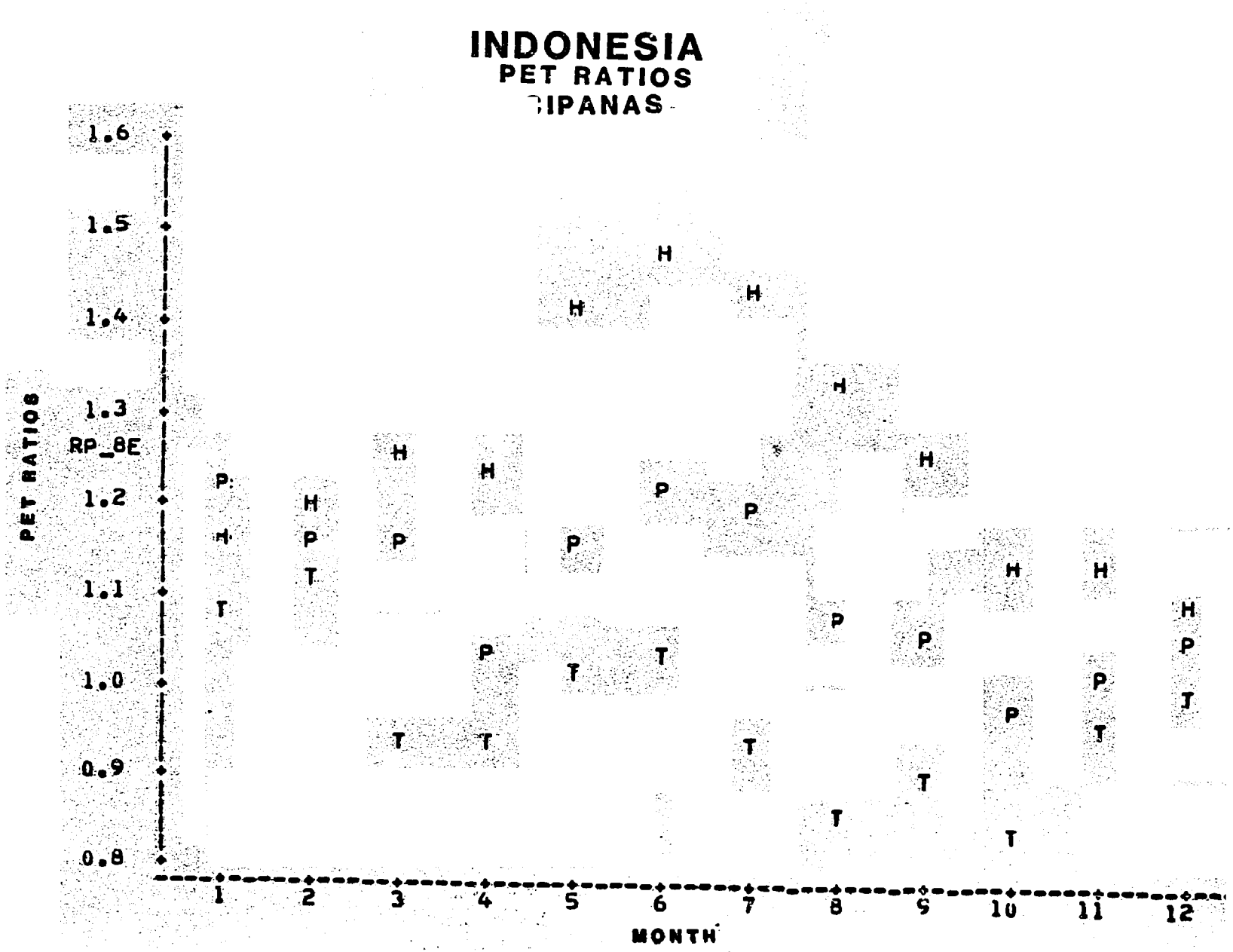


FIGURE 4.4b Comparison of Mean Monthly PET Ratios (P=Penman/.8Pan, H=Hargreaves/.8Pan and T=Thornthwaite/.8Pan) for Cipanas.

season. Evaporation rates are also higher during the dry season (4.1 mm per day) compared to the wet season (3.0 mm per day).

In Indonesia, where the main agroclimatic problems are drought and floods, evapotranspiration, rainfall and runoff play an important role. During the rainy season, usually with high rainfall intensity, the excess water from higher elevations can flood the lowlands. Generally, the highest runoff occurs from December thru February.

Preliminary findings include:

1) The adjusted pan evaporation and Penman method appear to be acceptable models for estimating PET in Indonesia. The Hargreaves method produces the next best results and the Thornthwaite method probably underestimates PET during the dry season and overestimates PET during the wet season. Both the Hargreaves and Thornthwaite methods should be used with caution. In higher elevation stations (i.e. Cipanas), the Thornthwaite method underestimates PET throughout the year.
2) Mean PET values can probably be used instead of individual calculations for many applications, e.g., soil moisture budget calculations. Rainfall is much more variable than PET or Pan.
3) PET can be estimated at data sparse locations by adjusting estimated PET's with the ratios of PET to pan or by interpolating PET and accounting for elevation changes.
4) Local station characteristics must be considered when interpolating or estimating PET for soil moisture or land use studies.
5) In many locations runoff during the rainy season is very high, reaching 600 to 1,000 mm per month. This excess of water causes plant nutrient losses by soil leaching, soil erosion on hillsides and eventually floodings in lowlands.

C. Climatic Diagrams

The monthly means of PET (Penman method), estimated actual evapotranspiration (AET) and rainfall at each agrometeorological station were plotted as shown in Figures 4.5a-d. The values of AET were determined from the Palmer two-layer model. Such plots are called climatic diagrams.

The climatic diagrams illustrate the general water supply (precipitation) and the water demand (AET); hence, general periods of water deficit or water surplus can be indicated. The diagrams represent one tool for application in land use studies. For example, in Figure 4.5d, the climatic diagram for the Pusaka Negara agrometeorological station suggests that water is adequate for the crops during November to April. This contrasts with May to October when water deficits will usually be experienced. The diagram provides general information on the crop calendar and growing season at Pusaka Negara. Planting should begin during November to avoid water deficit problems.

These diagrams could be made more useful if monthly mean soil moisture estimates were included. As previously discussed, the diagram could be determined for a particular crop by using crop coefficients. Finally, diagrams can be determined for other time periods such as decadal or weekly intervals. The diagram can be calculated each season for use in assessments and making an analysis for irrigation scheduling.

The climatic diagrams should be used along with other agroclimatic tools. For example, the diagrams complement agroclimatic/crop condition index models and statistical crop yield forecast models for assessing climate impact on crops. There are also many different tools for application to land and water management questions; the R-Index has been widely used in land suitability studies.

INDONESIA
CLIMATIC DIAGRAM
CIPANAS

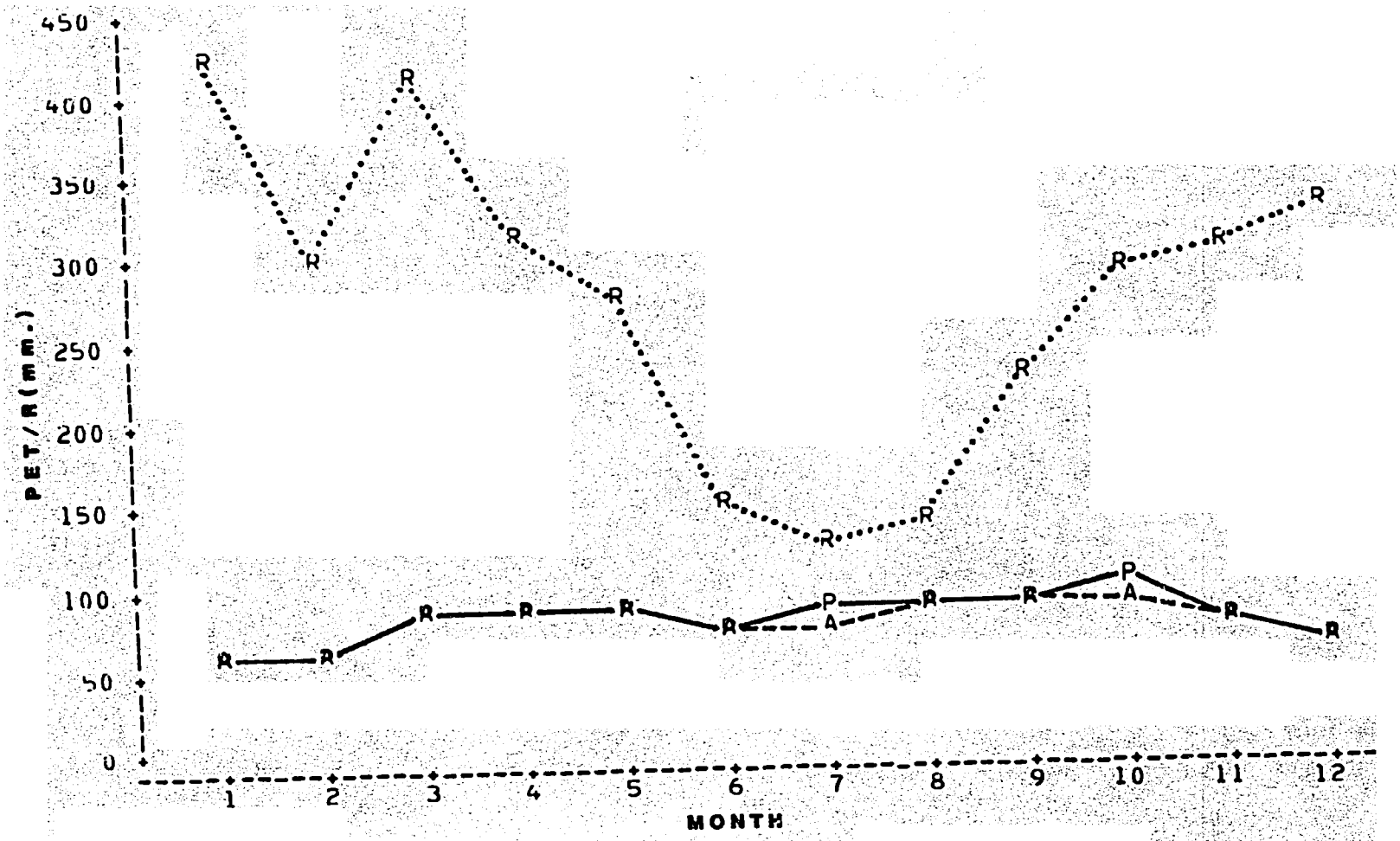


FIGURE 4.5a Climatic Diagram for Cipanas (Normals for: P=Penman PET, A=Actual Evapotranspiration and R=Rainfall).

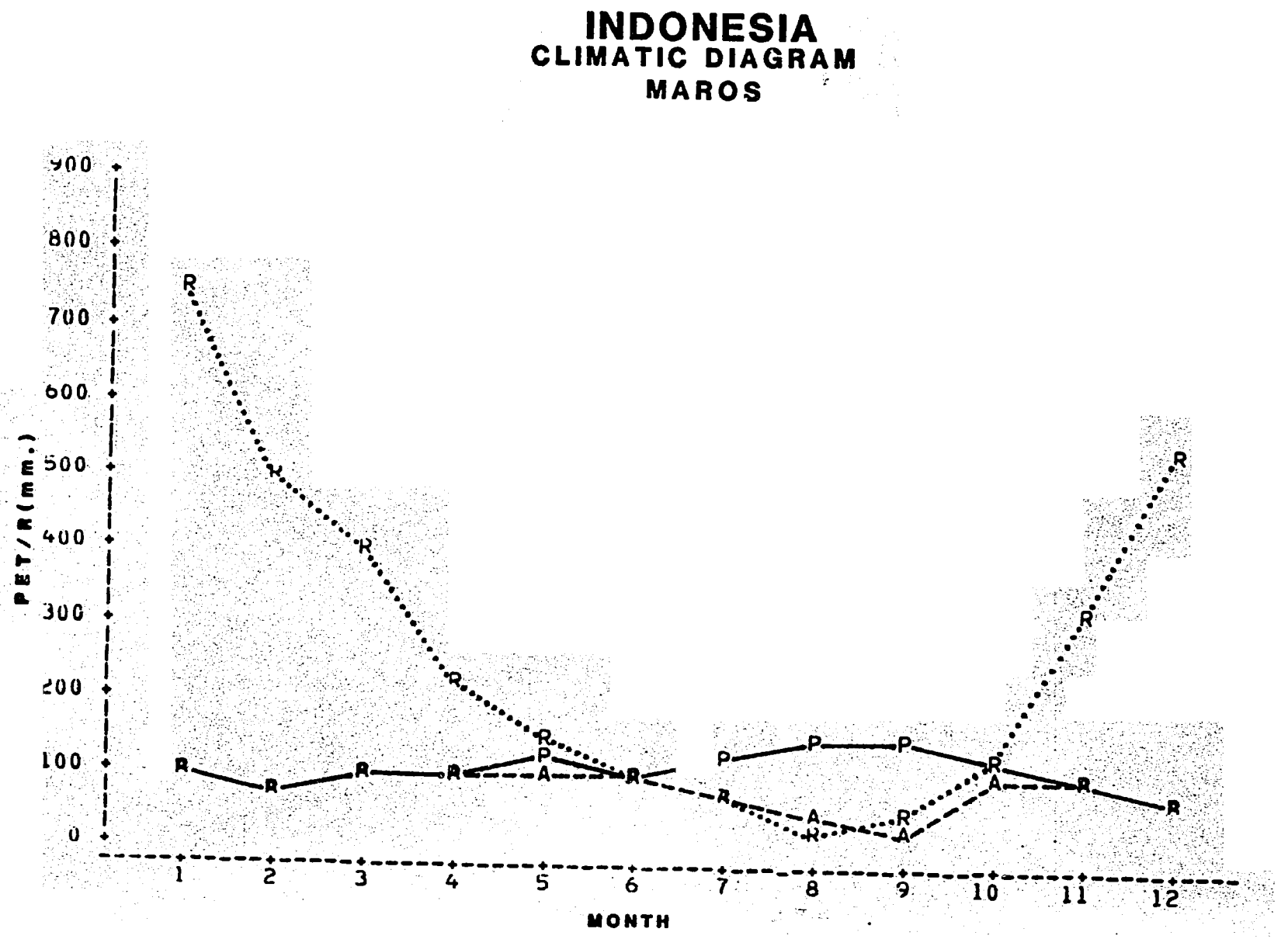


FIGURE 4.5b Climatic Diagram for Maros (Normals for: P=Penman PET, A=Actual Evapotranspiration and R=Rainfall).

INDONESIA
CLIMATIC DIAGRAM
MOJOSARI

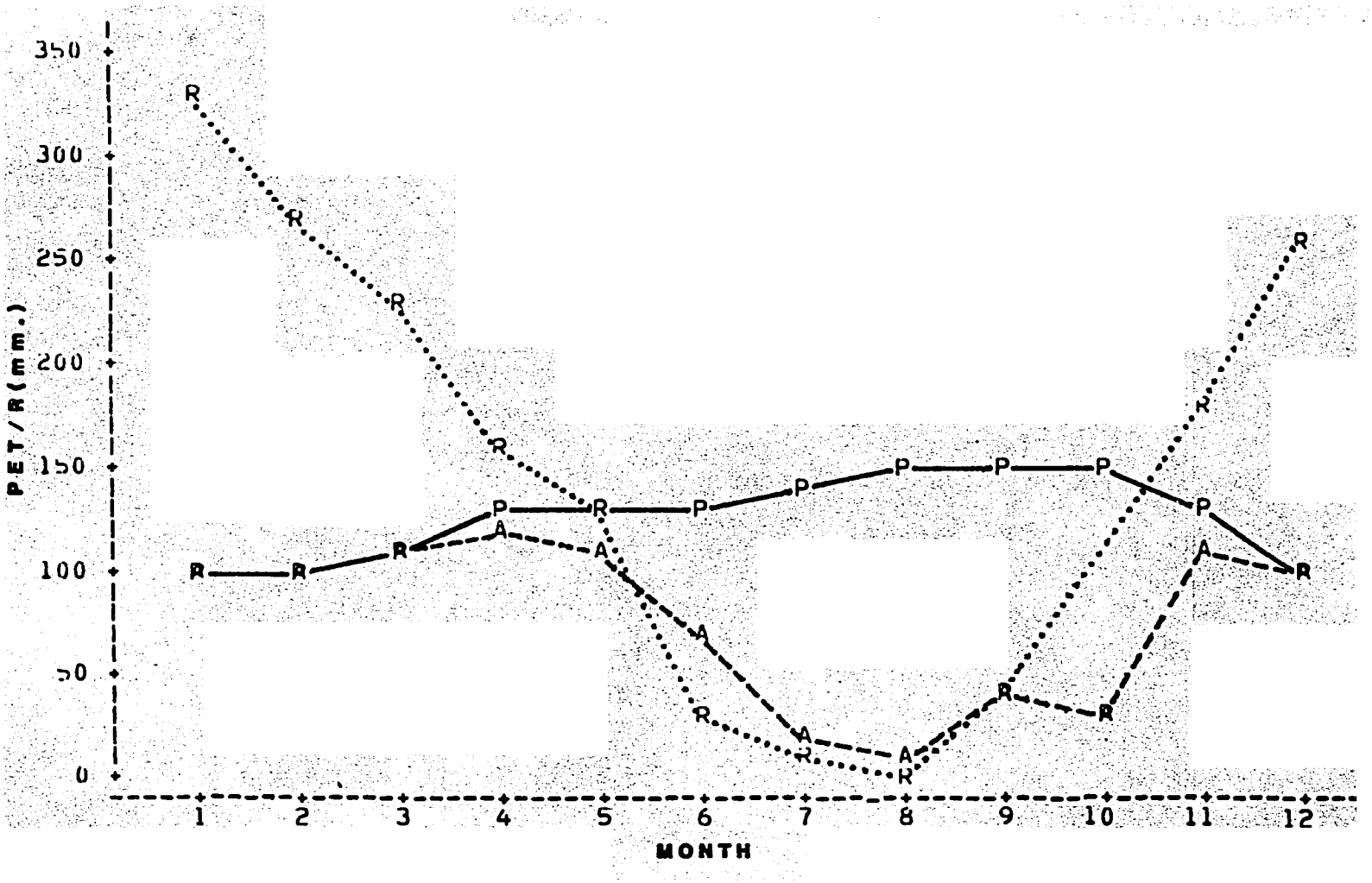


FIGURE 4.5c Climatic Diagram for Mojosari (Normals for: P=Penman PET, A=Actual Evapotranspiration and R=Rainfall).

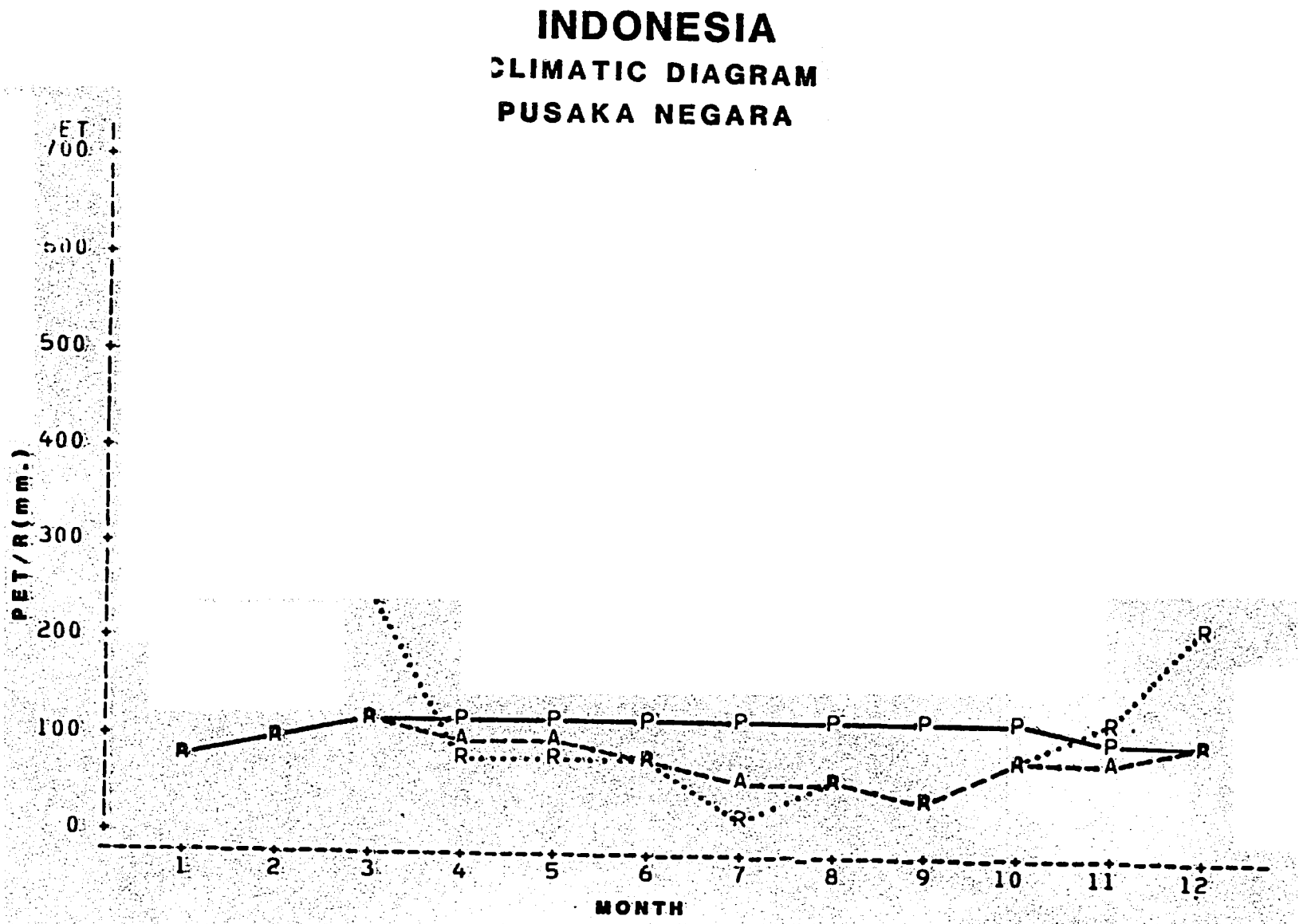


FIGURE 4.5d Climatic Diagram for Pusaka Negara (Normals for: P=Penman PET, A=Actual Evapotranspiration and R=Rainfall).

CHAPTER V

CLIMATIC IMPACT ASSESSMENT MODELING RESULTS

Climatic impact assessment models which were developed for Indonesia include: 1) agroclimatic/crop condition indices for rice and maize, 2) soil moisture assessment procedures and 3) a statistical climate/crop yield forecast model for main rice. These assessment models are based on relationships which reflect the biological (or agronomic) response of the crop to moisture and temperature anomalies during the growing season, particularly during the critical flowering/reproductive crop stages. Although all the models require thorough test and evaluation, they provide a solid foundation for assessing climatic impact on crops during the growing season.

This chapter includes information on the history of crop yield modeling, analytic steps for model development, discussion of the proposed assessment models for Indonesia and suggestions for test and evaluation of the models.

A. Background

During the decade of the 1970's, significant advances were made in the development and application of climatic impact assessment models for agriculture. The success of this applied modeling is associated with the increased availability of computers which permitted scientists to develop the models coupled with the critical need for climate impact information. Decision makers, planners and economists have come to recognize that this approach can provide timely, reliable and yet inexpensive information concerning climatic impact on crop yields and agricultural production. It has become recognized that these models can supplement and complement other information sources, e.g., crop information sources including farm and marketing reports, probability surveys involving area farm analysis, census, demand side economic analysis and others.

Models are also being used to provide early warning of potentially disastrous food shortages resulting from severe drought. For example, the United Nations, Food and Agricultural Organization (UN/FAO) and the U.S. National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information System, Assessment and Information Services Center (NOAA/NESDIS/AISC) are two organizations involved in this type of effort. The AISC program provides support to the Office of U.S. Foreign Disaster Assistance, Agency for International Development (AID/OFDA).

Types of Crop Yield Models

There are essentially three types of crop yield models: 1) statistical climate/crop yield models, 2) agroclimatic/crop condition index models and 3) the phenologic or "process" models.

The statistical model is based on multiple linear regression analysis using historic climatic data and crop yield. These models provide absolute yield forecasts. Statistical models have been developed or at least attempted for many geographic regions in the world, particularly major grain producing areas. Some of the crops modeled include wheat, corn, barley, soybeans, sorghum/millet, rice, cotton, sunflower, flax, groundnuts, sesame, sugarcane, oil palm and others.

The second type of model is the agroclimatic/crop condition index which is also based on historic climatic data. This approach has become increasingly popular to assess crop conditions and to obtain relative crop yield information. The index is based on an agroclimatic variable such as cumulative precipitation, PET, ET/PET, soil moisture, and others directly associated with the year-to-year variations in crop yield. The index provides a measure of climatic impact on the crop, particularly for drought impact assessment.

The agroclimatic variable on which the index is based could be viewed as that predictor variable which would produce a statistically significant regression model, if reliable yield data were available. The choice of the proper agroclimatic variable can be determined by: 1) knowledge of those climatic conditions which determine yield, particularly in marginal, semi-arid production regions where crops are rainfed, 2) information on the appropriate variables determined by regression analysis for similar regions and 3) episodic event data on the historical causes (both weather and non-weather factors) of crop failure or bumper crops. For example, published reports, newspaper articles, discussions with farmers and other sources of information can be used to assemble these qualitative accounts for many different years. Episodic data can also be used to interpret or "calibrate" the indices for a particular region. For example, the index can be computed from 20-30 years of historic climatic data and plotted as a time-series. The values of the index are entirely relative and can be expressed in raw numbers, percent of some base year, percentiles, standard deviations, etc. Episodic reports on the failure of crops due to drought may suggest, for example, that "historically crop failure is associated with index values which are below the 20th percentile or equivalently 60 percent of normal."

The third type of model is the phenologic or "process" model which is based on plant processes such as photosynthesis. Although these models are still in the research and development stage, they show promise. They were designed primarily to simulate the growth and development of a plant, for example, cotton, maize, wheat and sorghum. The models have been used as a farm management tool,

for example, to examine various strategies for increasing production. The models are being tested to determine if they can be used to provide assessment information on crop phenology and relative yields for a large area such as a province. The models work best in the regions where they were developed, but potentially can be adapted for application in other areas.

Applications

The statistical crop models and the agroclimatic/crop condition index models are primarily drought impact models. Excessive moisture or flooding conditions are usually quite difficult to model. However, a skilled analyst can use the models to provide very useful crop yield information. The capabilities (when the model works) and limitations (when the model does not work) of the model must be used as guidelines for interpreting the output of the model.

Statistical climate/crop yield models can be used for other applications. For example, long-term records of climatic data can be used to simulate yield well beyond the period of record for observed yield data. Yield is an integrator of climate and the model converts climate data into simulated yield. Simulated yields can be used to determine the risk of crop failure, estimate probabilities of crop failure (2 or 3 consecutive years, etc.), estimate various probabilities for simultaneous crop failure in two or more regions and in the analysis of climatic trend. For example, an often overlooked fact is that trends in yield or production can also be associated with long-term trends in rainfall. Sometimes trend in yield due to climate trend can also be associated with trend in yield due to improved technology or decreased soil fertility.

Steyaert, Achutuni and Ravelo (1979) used a statistical crop yield model to investigate the vulnerability of maize to drought in Haiti due to soil erosion. They found that soil erosion (associated with deforestation) and the reduced

water holding capacity of the soil resulted in increased vulnerability of maize to drought, i.e., shallow soil cannot store as much water to carry the crop through dry spells.

Crop yield models can be important tools for land use studies or analysis of climatic change. (What happens to yield if rainfall decreases by 50 percent?) The models can increase awareness and knowledge about those climatic conditions which affect yield. Finally, the models can in some cases be used as a basis for farmer's advisories, e.g., recommended planting date, irrigation scheduling, and fertilizer applications (see Steyaert et al, 1981).

B. Analytic Steps to Model Development

Year-to-year changes in crop yield can be caused by weather events (frost, flooding, winds, etc.), climate (drought, anomalously "wet" years, low solar radiation, etc.), management decisions (planting date, weed and pest control, water control, tillage practices, etc.), and/or technology (variety, fertilizer and pesticide applications, irrigation, etc.). These factors plus soil determine the potential yield. Trends in yield can be associated with either changes in technology (e.g., increased technology impact each year), trend in climate or both.

The above factors suggest the need for several different types of data bases: meteorological, crop statistics (area, yield and production), technology data and episodic data as previously described. Detailed information on crop calendars and agricultural practices are also necessary.

The first requirement is to assemble the available data and thoroughly perform quality control checks. The reliability and adequacy of meteorological and yield data must be determined. Too much emphasis cannot be placed on this step.

The modeler must become very familiar with agricultural practices and the

factors which cause yield variability. The candidate predictor variables, role of technology, and significance of decadal, monthly or seasonal predictor variables must be determined.

In the traditional statistical climate/crop yield models, the basic predictor variables are monthly precipitation, temperatures or derived indices such as the R-Index. If technology has caused a time trend in yield, a time or year term has traditionally been used as a surrogate variable for technology. The time trend variable can be included as a predictor variable in the model development.

Scatter diagrams and linear correlations are used to select preliminary predictor variables which must be statistically related to yield as well as biologically related to the crop. Linear regression analysis is used to develop the model. The final models must be tested and evaluated.

Scatter diagrams and linear correlations are used to select preliminary predictor variables which must be statistically related to yield as well as biologically related to the crop. Linear regression analysis is used to develop the model. The final models must be tested and evaluated.

Some of the advantages and disadvantages of statistical climate/crop yield models are:

Disadvantages

1) They use a fixed crop calendar, i.e., it is assumed that the planting and vegetative growth stages, etc., occur at the same time each year. Therefore, if a delay in planting occurs, the model may not be able to respond.

2) Monthly data are often used. Crops are also responsive to more frequent changes in the weather or climate.

3) Shorter period weather phenomena, especially episodes such as extreme temperatures, high winds, freeze, or flooding cannot be modeled very well.

4) Episodes usually do not occur frequently enough to do a quantitative analysis.

5) Regression models tend to predict "close to the mean yield" and do not predict extremes very well. The models should not be used to predict independently outside of the range data.

6) The models use linear trend as a surrogate for technology. If not objectively specified, the trend term can be very misleading in the development and use of the model. Linear trend is used because the technology data are generally not available or are of low quality. Furthermore, no one has devised a statistical method of combining weather and technology data.

7) Future climate/crop relationships may change from historical relationships used to develop the model. For example, varieties could change such as traditional varieties to high yielding varieties. The climatic responses could be different.

Advantages

1) These models are based on the statistical/agronomic/physical significance between the climatic data and crop yield data. Physical significance means that any weather or climatic variable used in the model has a high degree of biological relationship with the known effect on the crop.

2) Models represent straight-forward relationships that make minimal assumptions and permit the yield data and climatic data to define the model according to historical interrelationships. They make the maximum use of historical climatic data and yield which is an integrator of climate.

3) The models are inexpensive to operate and produce useful information, particularly if they are evaluated according to strengths and weaknesses along with other crop yield or crop condition forecast procedures. The models should be used to supplement other sources of information.

C. Agroclimatic/Crop Condition Indices

Agroclimatic/crop condition indices based on the GMI and YMI were developed for assessing drought impact. The GMI was calculated for each of the 56 stations indicated in Figure 3.1. The YMI for the first and second rice and maize crops were also calculated at these same stations. Both indices should be used in preparing the climatic impact assessments.

1) Generalized Monsoon Index (GMI)

The GMI for the Southeast Monsoon season is based on April through July monthly precipitation data. The weights for each month are 0.15 for April, 0.25 for May, 0.40 for June and 0.20 for July. The index is accumulated at the end of each month. Similarly, the GMI for the Northwest Monsoon season is based on November through February precipitation. The corresponding weights for each month are 0.15 for November, 0.30 for December, 0.30 for January and 0.25 for December.

The monthly rainfall data (P1 = Jan, P2 = Feb, etc.) and the associated sample means (NP1 = Jan, NP2 = Feb, etc.) from the period of record for the meteorological stations in the Java region are indicated in Table 5.1. These data are also listed by station.

The GMI analysis for the 1974 Northwest Monsoon season at all stations in Java is shown in Table 5.2. The GMI is expressed in millimeters at the end of each cumulative time period: GMI_P11 at the end of November, GMI11_12 at the end of December, GMI 11_1 at the end of January and GMI 11_2 at the end of January. The "normal" (i.e., sample mean) GMI at each period is shown: NGMI_P11 at the end of November, NGMI11_12 at the end of December, etc. The percent of normal

Table 5.1 Observed and Normal Precipitation (mm) by Stations

COUNTRY=INDONESIA REGION=JAVA YEAR=1978

STATION	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
ADISUCIPTO	286	217	272	124	181	337	218	54	66	94	45	235
BANYUWANGI	275			60	144	244	89	112	171	36	132	255
CIPANAS	340	267	417	204	231	288	317	188	417	259	207	344
GENTENG	412	194	330	176	250	316	213		311	171	151	247
HALIM PERDANAKASUMA	404	169	176	156	97	234	63	144	151	107	252	161
JAKENAN	431	162	209	95	181	121	118	62	36	107	118	332
KALIANGET (METEO)	432	172	376	61	149	220	26	57	20	63	92	225
KALIBANTENG	531	176	459	138	257	139	76	131	218	218	358	335
KEMAYORAN	262	365	215	71	127	129	115	93	118	123	93	337
KENDAL_P	302	302	168	123	191	257	142	28	35	166	230	252
KUNINGAN	284	363	281	182	216	176	206	23	49	171		413
MARGAHAY	292	108	424	157	181	280	131	113	20	454	262	390
MOJOSARI	451	284	142	127	234	65	27	27	72	13	69	421
MUARA	410	241	508	244	311	366	329	450	517	539	467	552
NGALE	316	370	315	129	235	193	46	79	106	134	209	196
PUSAKANE	343	232	215	85	113	119	98	185	53	137	171	245
SANGKAPURA		196	419	170	311	388	181	21	68	168		616
SERANG	236	203	284	121	31	146	100	99	91	121	80	252
TAMANBOG	224	286	417	229	157	358	191	158	285	117	358	387
TANJUN PEREK (METEO)/SURABAJA	756	489	138	133	107	20	25	50	46	42	85	343
TASIKMALAYA/CIBEUREUM	278	281	206	168	358	458	128	239	317	447	374	366
TJILATJAR/CILICAP	392	177	315	195	420	725	668	360	175	398	239	408

STATION	NP1	NP2	NP3	NP4	NP5	NP6	NP7	NP8	NP9	NP10	NP11	NP12
ADISUCIPTO	353	318	331	156	124	54	45	42	36	108	173	272
BANYUWANGI	196	169	155	73	86	70	59	39	46	57	85	149
CIPANAS	401	351	445	403	345	255	183	215	227	311	300	328
GENTENG	335	215	210	112	184	162	151	50	148	126	120	188
HALIM PERDANAKASUMA	354	291	217	172	162	91	63	70	86	124	175	210
JAKENAN	261	222	223	141	126	56	50	29	38	77	153	231
KALIANGET (METEO)	237	228	210	133	139	65	42	15	10	39	98	218
KALIBANTENG	602	204	362	201	213	47	48	107	106	121	279	259
KEMAYORAN	425	302	213	112	97	74	54	54	46	88	108	174
KENDAL_P	273	249	253	139	133	75	40	8	44	112	279	300
KUNINGAN	223	334	275	207	231	101	50	48	68	139	215	332
MARGAHAY	177	174	245	275	184	121	89	72	121	257	334	283
MOJOSARI	331	265	234	159	132	28	7	5	43	34	178	260
MUARA	419	323	315	322	246	151	160	187	213	262	311	295
NGALE	218	222	234	284	189	89	33	26	81	157	348	204
PUSAKANE	559	311	264	83	78	77	28	62	42	70	118	227
SANGKAPURA	400	219	294	189	203	130	72	11	59	147	170	414
SERANG	279	237	193	124	114	76	80	73	72	100	140	195
TAMANBOG	391	424	274	170	185	191	138	105	212	206	303	370
TANJUN PEREK (METEO)/SURABAJA	273	257	219	143	102	45	32	17	15	37	128	265
TASIKMALAYA/CIBEUREUM	375	342	362	252	266	173	187	136	151	307	329	380
TJILATJAR/CILICAP	259	240	289	284	299	263	239	204	167	382	480	361

GENERALIZED MONSOON INDEX
(NORTHWEST)

GMI COEFFICIENTS: WEIGHT11= .15 / NOVEMBER
WEIGHT12= .30 / DECEMBER
WEIGHT1 = .30 / JANUARY
WEIGHT2 = .25 / FEBRUARY

---------- YEAR=1974 COUNTRY=INDONESIA REGION=JAVA ----------

STATION	GMI P11	NGMI P11	PGMI11	PLGM11	GMI11T2	NGMI11T2	PGMI11T2	PLGM11T2	GMI1T	NGMI1T	PGMI1T	PLGM1T	GMI1Z	NGMI1Z	PGMI1Z	PLGM1Z
ADISUCIPTO	33	26	125	70	82	108	76	37	164	213	77	28	237	293	81	30
AGRABINTA	142	80	178	84	168	194	87	32	260	285	91	44	336	337	100	68
BANDUNG/HUSEIN	41	38	105	56	96	116	82	28	156	184	84	24	206	235	88	28
BANYUWANGI	19	13	148	75	71	57	123	67	103	116	89	48	137	158	86	40
BENDO	41	27	151	75	122	100	122	65	254	204	124	73	336	274	123	73
BONGOS	38	78	49	14	211	308	68	12	447	585	76	24	681	800	85	24
DONDOWOSO	23	29	73	37	100	125	80	33	222	255	87	44	301	353	85	27
GEGER/GESEK	38	29	133	70	109	105	104	55	136	193	71	7	163	249	66	3
HALIM PERDANAKASUMA	22	26	85	39	96	89	108	68	179	195	92	52	267	268	100	57
JAKENAN	35	23	151	77	74	92	80	35	132	171	77	32	170	226	75	22
KALIANGET (METEO)	19	15	132	63	153	80	191	96	197	151	130	75	234	208	112	65
KEMAYORAN	15	16	92	50	55	58	81	48	116	196	59	16	223	271	82	30
KUNINGAN	39	32	120	75	143	132	109	62	255	199	128	75	300	282	106	62
MAGELANG	125	57	217	93	290	176	165	93	433	299	145	84	504	388	130	76
MALINGPING	97	60	162	85	249	191	130	85	331	307	124	85	483	393	123	74
MAOSPATI (METEO)	40	28	144	80	102	99	103	55	183	173	105	67	263	242	109	64
MOJOSARI	15	27	54	33	105	105	100	55	176	204	86	38	232	270	86	22
PASIRIAN	54	32	168	81	111	103	108	57	167	163	102	53	200	215	93	38
PEKALONGAN	8	18	45	24	105	101	104	57	139	268	52	10	191	382	50	3
PUSAKANE	23	18	130	66	74	86	87	44	140	253	55	22	199	331	60	22
RINGNIPINTU/TEGALDLIMO	33	19	172	82	78	85	91	42	129	150	86	40	187	207	90	38
SERANG	27	21	123	78	112	79	141	78	188	163	115	66	234	222	105	50
SUMBER PADAS	34	20	175	88	103	94	110	68	196	181	109	73	268	253	106	61
TANJUN PEREK (METEO)/SURABAJA	22	19	117	55	98	99	99	73	159	181	88	48	199	245	81	35
TASIKMALAYA/CIBEUREUM	54	49	109	56	183	163	112	64	309	276	112	73	387	361	107	63
TEGAL	15	18	83	53	100	90	111	64	184	192	96	53	226	274	82	34
TJILATJAR/CILICAP	113	72	157	88	172	180	95	46	187	259	73	10	274	318	86	29
WELERI	29	29	102	54	62	104	60	10	129	273	47	11	173	362	48	3
WURYANTORO	43	28	151	85	100	117	86	28	207	221	94	55	299	304	98	59

TABLE 5.2 Generalized Monsoon Index Analysis During the 1974 Northwest Monsoon Season for Stations in Java Province.

GMI for 1974 at each station is shown: PGMI11 at the end of November, PGMI1112 at the end of December, etc. The 1974 GMI values at each station are also expressed in percentiles which were determined from the historic record at each station. The percentile variable is: PLGMI11 at the end of November, PLGMI1112 at the end of December, etc.

Table 5.3 shows the GMI at Pasirian in East Java for the period 1951-1976. The variable names are similar to those in Table 5.2. Similar tables were developed for other stations and there are provisions at the bottom of each table for calculating the GMI in order to make assessments during the period following 1976.

Figure 5.1 shows the time-series plot of the GMI (expressed in percentiles) at Pasirian during the period 1951-1976 and at the end of each assessment month (N = November, D = December, etc.) Similar plots have been developed for other stations. This type of a graphical representation is very helpful in studying the year-to-year variations of the GMI at a particular station.

For example, the percentiles at the end of December, January and February of 1969 at Pasirian in East Java were all below the 10th percentile. Such low index values suggest extremely dry conditions at Pasirian, indicating the possibility of severe drought impact. Episodic event data can be used to verify these conditions.

The GMI is primarily designed to assess drought impact. However, GMI values above the 80-90th percentiles <u>may</u> be indicating flood situations. These need to be verified by using episodic data and local experience.

One of the primary tasks to be accomplished during test and evaluation is the "calibrated interpretation" of the GMI (this also applies to the other index models). Again, episodic event data and local experience are useful guides. Preliminary criteria for the critical thresholds for interpreting the GMI could

GENERALIZED MONSOON INDEX
(NORTHWEST)

GMI COEFFICIENTS: WEIGHT11= .15 / NOVEMBER
WEIGHT12= .30 / DECEMBER
WEIGHT1 = .30 / JANUARY
WEIGHT2 = .25 / FEBRJARY

COUNTRY=INDONESIA REGION=JAVA STATION=PASIRIAN

YEAR	GMI B11	NGMI B11	PGMI 11	PLGMI 11	GMI 1T2	NGMI 112	PGMI 112	PLGMI 112	GMI 1T	NGMI 1T	PGMI 1T	PLGMI 1T	GMI 1Z	NGMI 1Z	PGMI 1Z	PLGMI 1Z
1951	7	32	20	14	76	103	74	16	148	163	90	30	212	215	98	46
1952	49	32	153	77	115	103	112	77	151	163	93	34	199	215	93	34
1953	24	32	75	37	79	103	76	24	132	163	93	38	186	215	86	24
1954	42	32	131	70	138	103	135	88	197	163	121	84	224	215	10[illegible]	65
1955	32	32	98	48	76	103	74	16	113	163	69	7	157	215	73	7
1956	12	32	37	22	73	103	71	11	128	163	78	13	162	215	75	15
1957	25	32	79	40	92	103	90	33	128	163	78	13	160	215	74	11
1958	28	32	87	44	125	103	122	85	217	163	133	92	274	215	127	88
1959	32	32	100	51	112	103	109	66	173	163	106	63	257	215	119	76
1960	33	32	102	55	79	103	77	24	142	163	87	26	167	215	78	19
1961	5	32	14	3	54	103	53	7	176	163	108	71	249	215	116	73
1962	21	32	65	29	178	103	173	96	259	163	159	96	304	215	141	96
1963	6	32	20	11	100	103	97	44	133	163	81	19	209	215	97	42
1964	61	32	191	92	86	103	84	29	160	163	98	49	189	215	88	30
1965	36	32	112	59	112	103	109	66	170	163	104	57	213	215	99	49
1966	24	32	74	33	111	103	108	57	216	163	132	88	281	215	130	92
1967	6	32	19	7	112	103	109	66	173	163	106	63	220	215	102	53
1968	46	32	143	74	166	103	161	92	185	163	113	76	273	215	127	84
1969	12	32	38	25	52	103	51	3	90	163	55	3	114	215	53	3
1970	39	32	120	66	118	103	115	81	193	163	118	80	263	215	122	80
1971	57	32	176	85	102	103	99	68	157	163	96	44	223	215	104	61
1972	11	32	35	18	99	103	95	40	176	163	108	71	225	215	105	69
1973	59	32	183	88	104	103	101	51	139	163	85	23	222	215	103	57
1974	54	32	168	81	111	103	108	57	167	163	102	53	200	215	93	38
1975	37	32	114	62	114	103	111	74	157	163	96	44	186	215	87	24
1976	80	32	249	96	93	103	91	37								
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 5.3 Historical Generalized Monsoon Index (Northwest) Analysis for Pasirian in Java Province.

INDONESIA
GMI (NW) PERCENTILE PLOTS
PASIRIAN

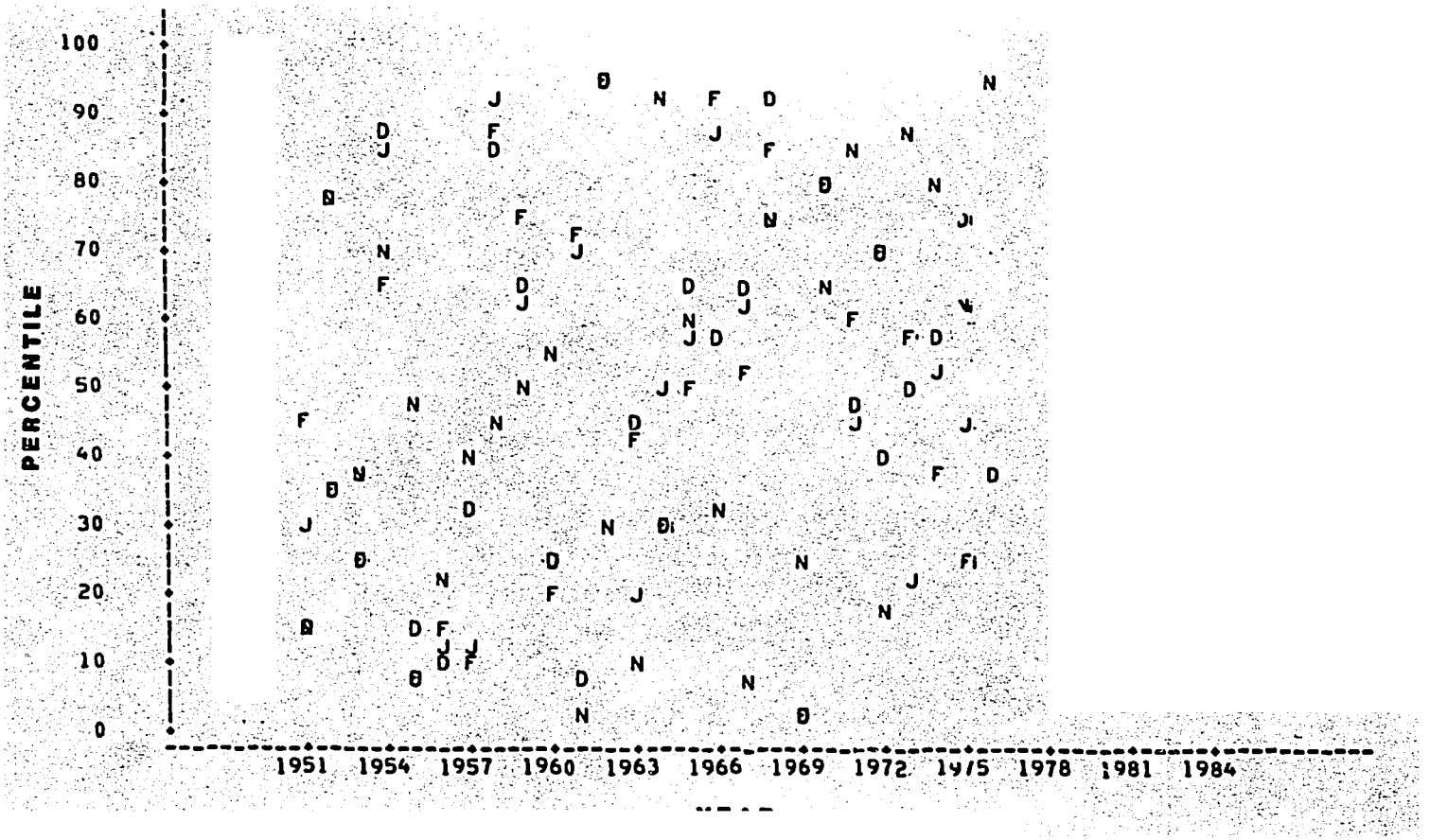


FIGURE 5.1 Percentile Rankings of the Generalized Monsoon Index (Northwest) at Pasirian in Java Province (N=November, D=December, J=January, F=February).

be: 1) 90-100th percentile range for possible excessive moisture, 2) 60-90th percentile range for possible above normal crops, 3) 40-60th percentile range for normal crops, 4) 30-40th percentile range for moderate drought impact on crops, 5) 20-30th percentile range for drought impact on crops and 6) 0-20th percentile range for severe drought impact and possible crop failure.

2. Yield Moisture Index (YMI)

The YMI was determined for the first and second maize and rice crops using crop calendar information, estimated crop coefficients, and monthly rainfall data at the same stations used in the GMI analysis. Although maize and rice were selected for the analysis, the YMI for other crops that are susceptible to drought could have also been used. AISC usually defines the YMI for short-cycle crops such as rice, maize, beans, sorghum, millets, etc., that are vulnerable to drought. Long-cycle, drought resistant crops such as cassava, cowpeas, etc., are not easily assessed by this index technique.

The YMI is directly analogous to the GMI; however, the YMI is crop specific and the GMI pertains to general crop conditions for crops planted in November.

YMI/Maize

In Indonesia, rice is generally grown during the main rainy season whereas maize is primarily grown during the secondary rainy season. Therefore second season maize refers to the maize crop planted during the secondary rainy season. The YMI for the first season maize crop was defined for planting in November, vegetative stage in December, flowering stage in January and maturity stage in February. The YMI for the second season maize crop was computed as follows: planting was defined to be in April, vegetative stage in May and flowering in June. The preliminary crop coefficients for each of these crop stages were presented earlier in Table 3.4b. The YMI is accumulated at the end of each stage. The index value and its relationship to potential drought impact becomes the most reliable at the end of flowering or maturity stage, depending upon whether

the crop is an early or late maturing variety.

Table 5.4 and 5.5 show the YMI for the secondary season maize crop at the stations in Java during 1974 and at Pasirian (1951-1976), respectively. The index is expressed in millimeters at the end of planting (YMI_4), vegetative (YMI_5), and flowering (YMI_6). "Normal" (or sample mean) values of the YMI determined from the period of record at each station are indicated, e.g., NYMI_4 at planting, etc. The percent of normal values (PNYMI_4 at the end of planting, etc.) are indicated. The percentile value for each crop stage are provided (e.g., PLYMI_4 for planting, etc.)

Figure 5.2 shows the historic plot of the YMI (in percentiles) for the secondary season maize crop at Pasirian in Java. The use of the YMI in assessments and the interpretation of the YMI is directly analogous to the discussion of the GMI, except the YMI is specifically designed for maize.

The percentiles indicated in Figure 5.2 can be interpreted as follows. The YMI at the end of planting ("4" for April in Figure 5.2), vegetative ("5" for May) and, flowering ("6" for June) stages is shown plotted for each year. The percentile value at the end of maturity also suggests relative maize yield, i.e., the maize yield relative to yields in other years. This type of index information can be converted into an estimate of absolute crop yield; however, this requires assumptions that usually are a subject of debate. Therefore, crop condition assessments should be confined to statements based on relative information (i.e., percentiles, percent of normal index, etc.). It should be noted that percent of normal YMI does not equate to percent of normal yield.

YMI/Rice

The YMI was computed for both the first and second rice crops. Tables 5.6 and 5.7 plus Figure 5.3 exemplify the development of the YMI for the first rice crop at individual stations in Java. The analysis is essentially the same as

YIELD MOISTURE INDEX

CROP COEFFICIENTS: KC4 = .65/ PLANTING /APRIL
KC5 = 1.05/ VEGETATION /MAY
KC6 = .75/ FLOWERING /JUNE

-------- YEAR=1974 COUNTRY=INDONESIA PROVINCE=JAVA CROP=MAIZE SEASON=SECOND --------

STATION	YMI 4	NYMI 4	PNYMI 4	PLYMI 4	YMI 5	NYMI 5	PNYMI 5	PLYMI 5	YMI 6	NYMI 6	PNYMI 6	PLYMI 6
ADISUCIPTO	119	101	117	61	253	232	109	62	254	272	93	60
BANJUWANGI	49	47	104	62	103	138	75	46	116	190	61	31
BENDO	138	163	85	50	294	393	75	35	339	480	71	25
JAKENAN	71	92	77	34	94	220	53	9	119	262	45	12
MADIUN/ISWAHYUDI	239	162	147	82	429	350	122	65	433	380	114	52
MAGELANG	511	217	235	95	720	459	157	84	720	530	136	72
MOJOSARI	117	103	113	70	124	242	51	20	162	263	62	30
PASIRIAN	24	94	26	7	214	250	56	40	220	315	70	25
PEKALONGAN	16	94	17	3	66	256	26	7	108	318	34	7
RINGNIPINTU/TEGALDLIMO	26	79	33	21	54	189	29	10	80	244	33	7
SUMBER PADAS	0	109	0	3	31	214	15	3	31	245	13	3
TANJUN PERAK (METEO)/SURABAJA	138	93	148	79	285	200	142	79	307	234	131	76
TEGAL	27	71	39	14	96	200	48	28	105	258	40	14
TJILATJAR/CILICAP	99	185	54	9	358	499	72	29	431	696	62	29
WELERI	55	123	45	17	171	270	53	28	223	343	65	28

TABLE 5.4 Yield Moisture Index Analysis for Maize Planted During the 1974 Secondary Rainy Season in Java Province.

Y I E L D M O I S T U R E I N D E X

CROP COEFFICIENTS:
KC4 = .65/ PLANTING /APRIL
KC5 = 1.05/ VEGETATION /MAY
KC6 = .75/ FLOWERING /JUNE

------ COUNTRY=INDONESIA PROVINCE=JAVA STATION=PASIRIAN CROP=MAIZE SEASON=SECOND ---

YEAR	YMI_4	NYMI_4	PNYMI_4	PLYMI_4	YMI_5	NYMI_5	PNYMI_5	PLYMI_5	YMI_6	NYMI_6	PNYMI_6	PLYMI_6
1951	40	94	42	16	47	250	19	3	140	315	44	11
1952	23	94	25	3	105	250	42	11	150	315	47	18
1953	75	94	81	37	247	250	99	44	250	315	79	37
1954	132	94	141	77	329	250	132	74	357	315	113	66
1955	60	94	65	29	128	250	51	18	368	315	117	70
1956	66	94	71	33	307	250	123	70	352	315	112	59
1957	79	94	85	40	142	250	57	29	247	315	78	33
1958	116	94	124	74	290	250	116	62	447	315	142	85
1959	175	94	187	92	337	250	135	77	458	315	145	88
1960	110	94	117	70	282	250	113	55	346	315	110	55
1961	55	94	60	25	122	250	49	14	140	315	44	14
1962	133	94	142	81	179	250	72	33	267	315	85	40
1963	107	94	115	66	283	250	113	59	286	315	91	48
1964	53	94	56	22	401	250	160	88	431	315	137	81
1965	103	94	110	55	137	250	55	22	154	315	49	22
1966	105	94	112	61	364	250	145	81	391	315	124	77
1967	135	94	144	85	139	250	55	25	139	315	44	7
1968	93	94	99	48	450	250	180	92	584	315	185	92
1969	102	94	109	51	190	250	76	37	236	315	75	29
1970	155	94	166	88	291	250	116	66	330	315	105	51
1971	40	94	42	16	274	250	109	51	355	315	113	62
1972	90	94	96	44	271	250	109	48	272	315	86	44
1973	212	94	226	96	543	250	217	96	844	315	268	96
1974	24	94	26	7	214	250	86	40	220	315	70	25
1975	105	94	112	61	367	250	147	85	370	315	117	74
1976	36	94	39	11	51	250	20	7	51	315	16	3
1977												
1978	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 5.5 Yield Moisture Index Analysis for Maize Planted During the Secondary Rainy Season at Pasirian in Java Province.

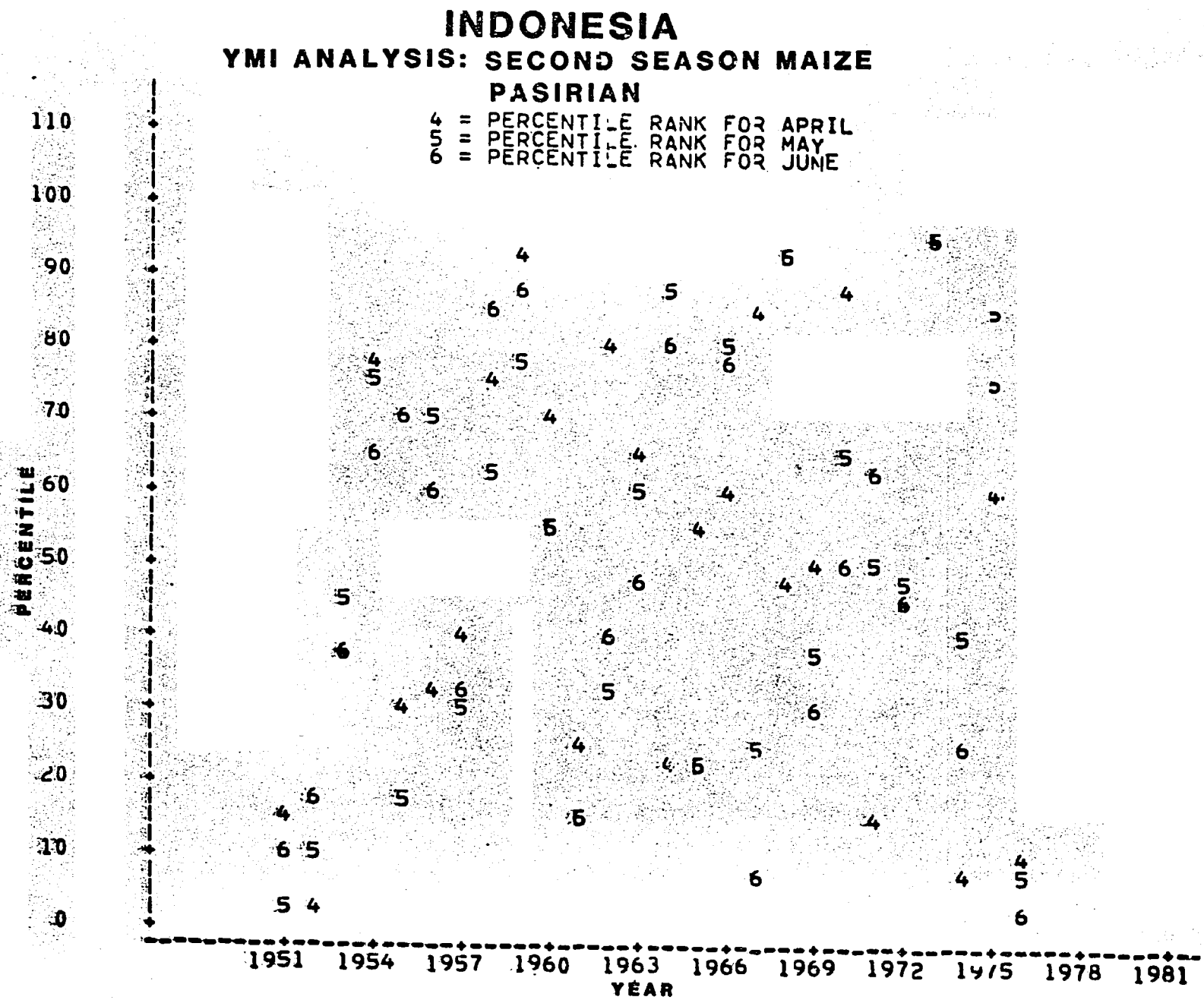


FIGURE 5.2 Percentile Rankings of the Yield Moisture Index for the Second Season Maize Crop at Pasirian in Java Province.

FIELD MOISTURE INDEX

CROP COEFFICIENTS:

KC11	=	.85/	PLANTING	/NOVEMBER
KC12	=	.95/	VEGETATION	/DECEMBER
KC1	=	1.05/	FLOWERING	/JANUARY
KC2	=	.95/	MATURITY	/FEBRUARY

---------- YEAR=1974 COUNTRY=INDONESIA PROVINCE=JAVA CROP=RICE SEASON=FIRST ----------

STATION	YMI T1	NYMI T1	PNYMI T1	PLYMI T1	YMI T2	NYMI T2	PNYMI T2	PLYMI T2
ADISUCIPTO	184	147	125	70	340	405	84	41
AGRABINTA	802	451	178	84	887	813	109	69
BANDUNG/HUSEIN	230	217	106	56	404	464	87	36
BANJUWANGI	107	72	148	75	271	214	127	68
BENDO	234	155	151	75	490	386	127	70
BONDOWOSO	129	166	78	37	372	469	79	33
BONGOS	218	443	49	14	763	1171	65	10
GEGER/GESER	216	162	133	70	441	405	109	55
JAKENAN	196	130	151	77	320	349	92	41
KALIANGET (METEO)	110	83	132	63	333	290	184	96
KEMAYORAN	84	92	92	50	212	257	83	44
MADIUN/ISWAHYUDI	227	158	144	80	423	382	111	66
MAGELANG	707	326	217	93	1231	701	176	93
MALINGPING	552	342	162	85	1031	755	137	85
MOJOSARI	82	151	54	33	368	398	92	44

STATION	YMI T1	NYMI T1	PNYMI T1	PLYMI T1	YMI T2	NYMI T2	PNYMI T2	PLYMI T2
ADISUCIPTO	629	776	81	33	906	1078	84	35
AGRABINTA	1208	1130	107	76	1497	1331	112	84
BANDUNG/HUSEIN	614	702	87	20	804	894	90	37
BANJUWANGI	384	420	91	48	513	580	88	43
BENDO	951	750	127	78	1253	1014	125	68
BONDOWOSO	800	924	87	38	1103	1295	85	26
BONGOS	1591	2140	74	14	2479	2956	84	22
GEGER/GESER	537	712	75	19	639	926	69	7
JAKENAN	522	624	84	38	659	834	80	22
KALIANGET (METEO)	688	539	128	72	826	753	109	62
KEMAYORAN	423	703	60	15	831	990	84	28
MADIUN/ISWAHYUDI	705	643	110	76	1009	903	112	71
MAGELANG	1731	1131	153	84	2000	1470	136	84
MALINGPING	1494	1161	129	88	1854	1490	126	85
MOJOSARI	618	746	83	33	829	998	83	22

TABLE 5.6 1974 Yield Moisture Index Station Analysis for First Season Rice in Java Province.

YIELD MOISTURE INDEX

CROP COEFFICIENTS:

KC11	=	.85/	PLANTING	/NOVEMBER
KC12	=	.95/	VEGETATION	/DECEMBER
KC1	=	1.05/	FLOWERING	/JANUARY
KC2	=	.95/	MATURITY	/FEBRUARY

---------- YEAR=1974 COUNTRY=INDONESIA PROVINCE=JAVA CROP=RICE SEASON=FIRST ----------

STATION	YMI T1	NYMI T1	PNYMI T1	PLYMI T1	YMI T2	NYMI T2	PNYMI T2	PLYMI T2	YMI T	NYMI T	PNYMI T	PLYMI T	YMI Z	NYMI Z	PNYMI Z	PLYMI Z
PASIRIAN	308	183	168	91	486	406	120	77	683	618	110	69	808	815	99	53
PEKALONGAN	48	104	46	24	353	365	97	57	471	951	50	7	669	1385	48	3
PUSAKANE	130	100	130	66	292	316	93	44	521	903	58	11	746	1198	62	11
RINGNIPINTU/TEGALDLIMO	185	108	172	92	328	319	103	64	507	545	93	44	727	762	95	40
SERANG	152	119	128	78	421	304	138	78	687	597	115	66	864	822	105	50
SUMBER PADAS	195	111	176	88	414	347	119	77	738	650	114	80	1012	924	110	76
TANJUN PERAK (METEO)/SURABAJA	127	109	117	56	366	361	101	66	581	647	90	39	733	891	82	35
TASIKMALAYA/CIBEUREUM	306	280	109	65	715	641	112	69	1154	1034	112	75	1451	1359	107	62
TEGAL	88	99	88	53	355	329	108	53	649	687	94	53	807	998	81	34
TJILATJAR/CILICAP	643	408	158	88	828	751	110	63	882	1023	86	35	1212	1251	97	48
WELERI	166	162	102	64	270	402	67	21	504	991	51	14	675	1330	50	3
WURYANTURO	241	160	151	85	424	440	96	49	794	804	99	53	1145	1119	102	61

TABLE 5.6 1974 Yield Moisture Index Station Analysis for First Season Rice in Java Province (continued).

YIELD MOISTURE INDEX

CROP COEFFICIENTS:

KC11	= .85/	PLANTING	/NOVEMBER
KC12	= .95/	VEGETATION	/DECEMBER
KC1	= 1.05/	FLOWERING	/JANUARY
KC2	= .95/	MATURITY	/FEBRUARY

------- COUNTRY=INDONESIA PROVINCE=JAVA STATION=PASIRIAN CROP=RICE SEASON=FIRST -------

YEAR	YMI T1	NYMI T1	PNYMI T1	PLYMI T1	YMI T2	NYMI T2	PNYMI T2	PLYMI T2	YMI T	NYMI T	PNYMI T	PLYMI T	YMI Z	NYMI Z	PNYMI Z	PLYMI Z
1951	37	183	20	14	257	406	63	11	508	618	82	23	752	815	92	34
1952	280	183	153	77	488	406	120	81	616	618	100	53	798	815	98	46
1953	138	183	75	37	310	406	76	18	567	618	92	30	694	815	85	23
1954	239	183	131	70	544	406	134	88	749	618	121	84	853	815	105	61
1955	179	183	98	48	319	406	79	22	448	618	73	11	615	815	76	15
1956	68	183	37	22	261	406	64	14	454	618	73	15	584	815	72	7
1957	144	183	79	40	355	406	89	37	480	618	78	19	601	815	74	11
1958	160	183	87	44	467	406	115	66	787	618	127	92	1005	815	123	84
1959	183	183	100	51	435	406	107	51	650	618	105	61	967	815	119	76
1960	186	183	102	55	331	406	82	29	553	618	89	26	648	815	80	19
1961	26	183	14	3	183	406	45	3	610	618	99	46	889	815	109	65
1962	119	183	65	29	615	406	151	92	900	618	146	96	1071	815	132	96
1963	36	183	20	11	331	406	82	25	448	618	72	7	736	815	90	30
1964	348	183	191	95	425	406	105	48	687	618	111	73	794	815	97	42
1965	205	183	112	59	446	406	110	55	649	618	105	57	810	815	99	57
1966	135	183	74	33	411	406	101	44	779	618	126	88	1024	815	126	88
1967	35	183	19	7	370	406	91	40	583	618	94	34	762	815	94	38
1968	261	183	143	74	640	406	158	96	707	618	114	76	1042	815	128	92
1969	70	183	38	25	195	406	48	7	328	618	53	3	419	815	51	3
1970	219	183	120	66	471	406	116	70	735	618	119	80	999	815	123	80
1971	321	183	176	85	464	406	114	62	659	618	107	65	908	815	111	69
1972	64	183	35	18	342	406	84	33	611	618	99	49	799	815	98	49
1973	334	183	183	88	477	406	118	74	599	618	97	38	914	815	112	73
1974	308	183	168	81	486	406	120	77	693	618	110	69	808	815	99	53
1975	209	183	114	62	453	406	112	59	605	618	98	42	716	815	88	26
1976	456	183	249	96	495	406	122	85								
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 5.7 Historical Yield Moisture Index Analysis for First Season Rice at Pasirian in Java Province.

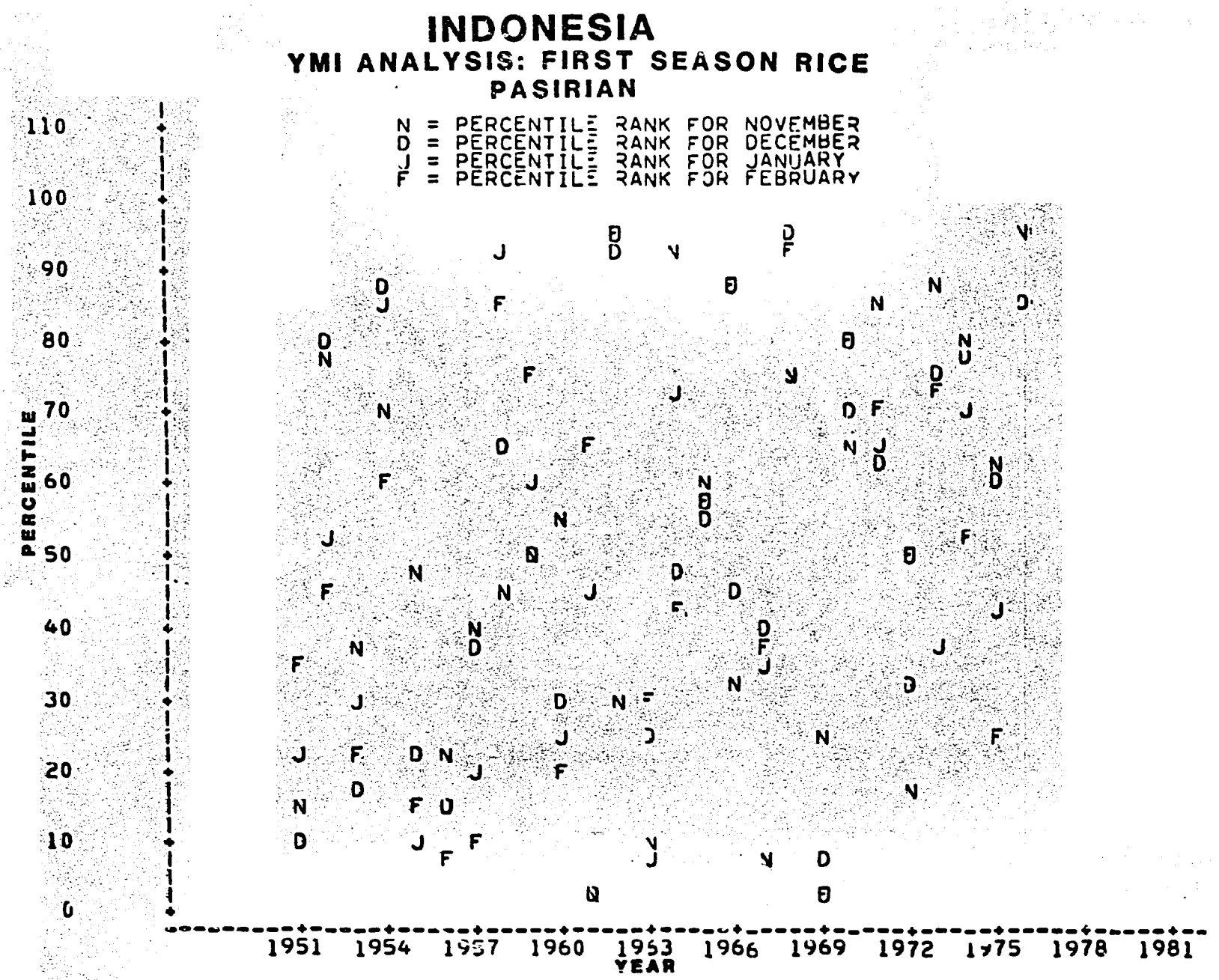


FIGURE 5.3 Percentile Rankings of the Yield Moisture Index for the First Rice Crop at Pasirian in Java Province.

for the YMI/Maize except for the crop calendar and crop coefficients. These include: 1) planting in November with a crop coefficient (KC) of 0.85, 2) vegetation in December with a KC of 0.95, 3) flowering in January with a KC of 1.05 and 4) maturation in February with a KC of 0.95 (Table 3.4b).

The crop calendar and crop coefficients for computing the YMI for the second rice crop include: 1) planting in April with a KC of 0.85, 2) vegetative in May with a KC of 0.95 and 3) flowering in June with a KC of 1.05. Short season varieties are generally planted for the second rice crop; the YMI is therefore not computed beyond the flowering stage (Table 3.4b)

D. Soil Moisture Assessments

The Palmer two-layer soil moisture budget model was used for illustrative purposes to estimate soil moisture at the following four stations: Cipanas, Maros, Mojosari and Pusaka Negara (Figure 3.1). The Penman PET method was used in estimating the monthly soil moisture budget.

Table 5.8 shows the soil moisture budget at Mojosari for the period 1977-1979. The corresponding Z-Index and Palmer Drought Index (PDI) values are shown in Table 5.9. A plot of the PDI for the period 1977-1980 is shown in Figure 5.4.

The soil moisture estimates can be incorporated into the assessments. The derived indices may also be useful in crop condition analysis. However, test and evaluation must be performed. Specifically, the analysis is based on an assumed maximum available water capacity (AWC) of 100.4 mm in the soil profile. This generally results in a full profile during the rainy season. The implication must be carefully evaluated.

INDONESIA
SOIL MOISTURE BUDGET
MOJOSARI

PALMER DROUGHT INDEX (PDI)
NAME=MOJOSARI 160

SOIL MOISTURE BUDGET FOR OBSERVATION # 22

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
SS	25.4000	25.4000	25.4000	24.2619	25.4000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	25.4000
SU	75.0000	75.0000	75.0000	75.0000	75.0000	56.9316	2.5934	0.0000	0.0000	0.0000	0.0000	75.0000
S	100.4000	100.4000	100.4000	99.2619	100.4000	56.9316	2.5934	0.0000	0.0000	0.0000	0.0000	100.4000
PCP	451.0000	284.0000	142.0000	127.0000	234.0000	65.0000	27.0000	27.0000	72.0000	13.0000	69.0000	421.0000
PET	102.6027	105.7601	112.2018	128.1381	129.5963	114.5875	122.8266	132.4969	133.0270	142.4982	121.9496	102.7500
ET	102.6027	105.7601	112.2018	128.1381	129.5963	108.4694	81.3383	29.7250	72.0000	13.0000	69.0000	102.7500
PR	0.0000	0.0000	0.0000	0.0000	1.1381	0.0000	43.4684	97.8066	100.4000	100.4000	100.4000	100.4000
R	0.0000	0.0000	0.0000	0.0000	1.1381	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.4000
PL	83.0714	85.4300	90.2420	102.1466	102.9479	92.0242	69.6486	3.4224	0.0000	0.0000	0.0000	0.0000
L	0.0000	0.0000	0.0000	1.1381	0.0000	43.4684	54.3383	2.7250	0.0000	0.0000	0.0000	0.0000
PRO	100.4000	100.4000	100.4000	100.4000	99.2619	100.4000	56.9316	2.5934	0.0000	0.0000	0.0000	0.0000
RO	348.3973	178.2399	29.7982	0.0000	103.2656	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	217.8500

SOIL MOISTURE BUDGET FOR OBSERVATION # 23

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
SS	25.4000	25.4000	12.5541	1.5095	25.4000	0.0000	0.0000	0.0000	0.0000	0.0000	5.4646	21.1374
SU	75.0000	75.0000	75.0000	75.0000	75.0000	20.8051	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S	100.4000	100.4000	87.5541	76.5095	100.4000	20.8051	0.0000	0.0000	0.0000	0.0000	5.4646	21.1374
PCP	376.0000	220.0000	109.0000	122.0000	235.0000	57.0000	0.0000	0.0000	13.0000	3.0000	138.0000	116.0000
PET	111.7319	99.6253	121.8459	133.0445	122.6602	124.3490	146.6363	159.5525	150.6048	143.6721	132.5354	100.3272
ET	111.7319	99.6253	121.8459	133.0445	122.6602	106.5949	30.3862	0.0000	13.0000	3.0000	132.5354	100.3272
PR	0.0000	0.0000	0.0000	12.8459	23.8905	0.0000	79.5949	100.4000	100.4000	100.4000	100.4000	94.9354
R	0.0000	0.0000	0.0000	0.0000	23.8905	0.0000	0.0000	0.0000	0.0000	0.0000	5.4646	15.6728
PL	89.8910	80.8472	97.4463	102.5619	92.0105	99.7643	30.3862	0.0000	0.0000	0.0000	0.0000	5.4646
L	0.0000	0.0000	12.8459	11.0445	0.0000	79.5949	30.3862	0.0000	0.0000	0.0000	0.0000	0.0000
PRO	100.4000	100.4000	100.4000	87.5541	76.5095	100.4000	20.8051	0.0000	0.0000	0.0000	0.0000	5.4646
RO	264.2681	120.3747	0.0000	0.0000	85.4493	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

SOIL MOISTURE BUDGET FOR OBSERVATION # 24

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
SS	25.4000	25.4000	25.4000	25.4000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	25.4000	25.4000
SU	75.0000	75.0000	75.0000	75.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	75.0000	75.0000
S	100.4000	100.4000	100.4000	100.4000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.4000	100.4000
PCP	283.0000	276.0000	135.0000	167.0000	21.0000	0.0000	0.0000	0.0000	0.0000	54.0000	255.0000	177.0000
PET	106.0156	97.7087	118.5921	122.0775	146.8531	143.7304	141.5529	152.7202	152.4961	147.1577	120.7961	96.7664
ET	106.0156	97.7087	118.5921	122.0775	121.4397	0.0000	0.0000	0.0000	0.0000	54.0000	120.7961	96.7664
PR	79.5626	0.0000	0.0000	0.0000	0.0000	100.4000	100.4000	100.4000	100.4000	100.4000	100.4000	0.0000
R	79.2626	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.4000	0.0000
PL	21.1374	79.4155	95.0156	97.6192	116.1269	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	78.7115
L	0.0000	0.0000	0.0000	0.0000	100.4397	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PRO	21.1374	100.4000	100.4000	100.4000	100.4000	0.0000	0.0000	0.0000	0.0000	0.0000	33.8039	100.4000
RO	97.7218	178.2913	16.4079	44.9225	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	80.2335

TABLE 5.8 Soil Moisture Budget for Mojosari (1977-1979).

PDI RESULTS

NAME=MOJOSARI

OBS	YEAR	PDI1	PDI2	PDI3	PDI4	PDI5	PDI6
17	1973	1.1358	0.6480	1.0163	1.4099	2.1440	2.1717
18	1974	-0.6521	0.7886	0.5275	0.5949	-0.8268	-0.8465
19	1975	-0.8175	-1.1047	-1.0493	1.6941	1.7957	1.6405
20	1976	-0.3423	-1.2611	0.7169	-1.1305	-1.7250	-2.4604
21	1977	-3.5850	-2.3122	-1.1959	-1.9556	-1.8372	-1.8545
22	1978	1.2664	1.2507	0.7772	-0.5755	0.9823	1.7272
23	1979	1.0884	0.5050	-0.9257	-1.1617	0.6509	0.9453
24	1980	-1.0653	-0.8404	-1.1477	-0.9720	-1.6472	-2.5056
25	1981	-2.1542	-1.6303	-2.0126	-1.9373	-1.7795	0.7667

OBS	PDI7	PDI8	PDI9	PDI10	PDI11	PDI12
17	-0.0407	-0.0484	-0.0445	-0.5809	0.6044	-0.7974
18	-1.0900	-0.8221	-1.1120	0.8769	0.3943	0.9574
19	1.4774	1.1733	2.4713	3.6369	3.3612	-0.1538
20	-2.7505	-2.6736	-2.9755	-3.1303	-3.5728	-3.0474
21	-2.2259	-2.1682	-2.6067	-3.0284	0.2806	0.6028
22	2.7614	3.4197	3.4904	-0.3608	-1.1564	1.1121
23	0.7432	0.4417	-0.7555	-1.2051	-1.3344	-1.5630
24	-2.7041	-2.6409	-3.0271	-2.4304	-1.1905	-1.8676
25	1.5084	1.2366	2.0100	1.8017	1.8860	1.5844

ZINDEX RESULTS

NAME=MOJOSARI

OBS	YEAR	ZINDEX1	ZINDEX2	ZINDEX3	ZINDEX4	ZINDEX5	ZINDEX6	ZINDEX7
17	1973	86.551	-28.256	33.149	37.966	67.005	18.943	-3.101
18	1974	4.813	55.778	-13.709	9.272	-60.291	-7.986	-25.199
19	1975	-62.291	-28.299	-4.450	129.090	21.037	2.268	0.448
20	1976	-15.569	-72.701	54.626	-57.827	-54.169	-69.581	-41.412
21	1977	-64.885	68.855	66.911	-67.275	-6.326	-15.740	-42.856
22	1978	55.299	8.740	-26.262	-20.295	45.405	64.471	92.361
23	1979	6.917	-35.911	-38.323	-25.254	49.600	27.540	-7.981
24	1980	25.659	8.780	-30.015	4.383	-59.081	-78.336	-34.793
25	1981	-36.493	23.015	-41.927	-10.061	-3.180	58.420	62.535

OBS	ZINDEX8	ZINDEX9	ZINDEX10	ZINDEX11	ZINDEX12	SS	SU	AWCS	AWCU
17	-0.907	-0.085	-41.224	46.057	-60.764	0	50	25.4	75
18	11.856	-28.543	66.821	-29.894	46.004	0	50	25.4	75
19	-11.575	108.115	108.217	7.538	-11.720	0	50	25.4	75
20	-15.727	-43.991	-35.151	-58.285	11.994	0	50	25.4	75
21	-13.069	-50.433	-52.592	21.385	26.751	0	50	25.4	75
22	71.834	32.229	-27.497	-63.451	84.745	0	50	25.4	75
23	-17.140	-35.770	-40.194	-19.309	-27.895	0	50	25.4	75
24	-16.406	-50.154	21.711	75.399	-60.939	0	50	25.4	75
25	-8.867	68.632	-0.091	20.560	-8.175	0	50	25.4	75

TABLE 5.9 Palmer Drought Index (PDI) and Z-Index Results for Mojosari.

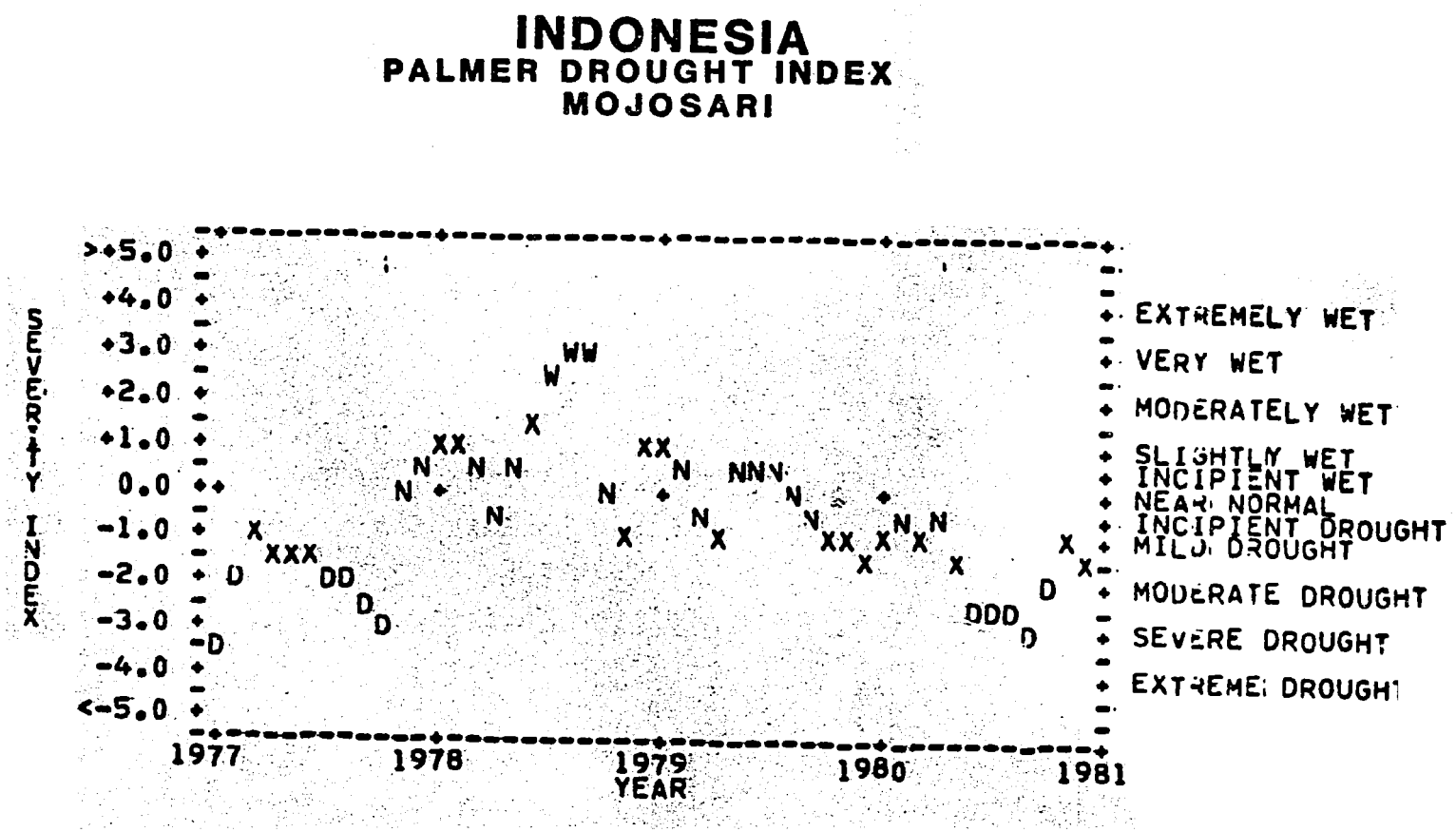


FIGURE 5.4 Palmer Drought Index Analysis (1977-1980) for Mojosari.

The Indonesian Meteorological Service has developed its own technique for estimating soil moisture on a decadal basis. It will be highly desirable to incorporate these decadal soil moisture estimates into future assessments as local conditions are taken into consideration by their technique.

E. Statistical Climate/Crop Yield Forecast Models for Indonesia

Statistical climate/crop yield models were attempted for main maize and dry-land paddy for select provinces in Indonesia. Although these preliminary models require thorough test and evaluation, they are promising. Testing should include evaluation of independent predictions for years not in the data base. The predictor variable in the models should be validated to ensure that they are biologically related to the crop and reflect vulnerability of the crop to climate anomalies which lead to yield losses.

Monthly precipitation and temperature were used as predictor variables in developing the linear regression models for maize and rice.

The linear regression models have the form:

$$\hat{Y} = a_o + \sum_{i=1}^{N} a_i x_i$$

where:

$\hat{Y}$ is the predicted yield (mt/ha),

a_o is the regression constant (i.e., intercept), and

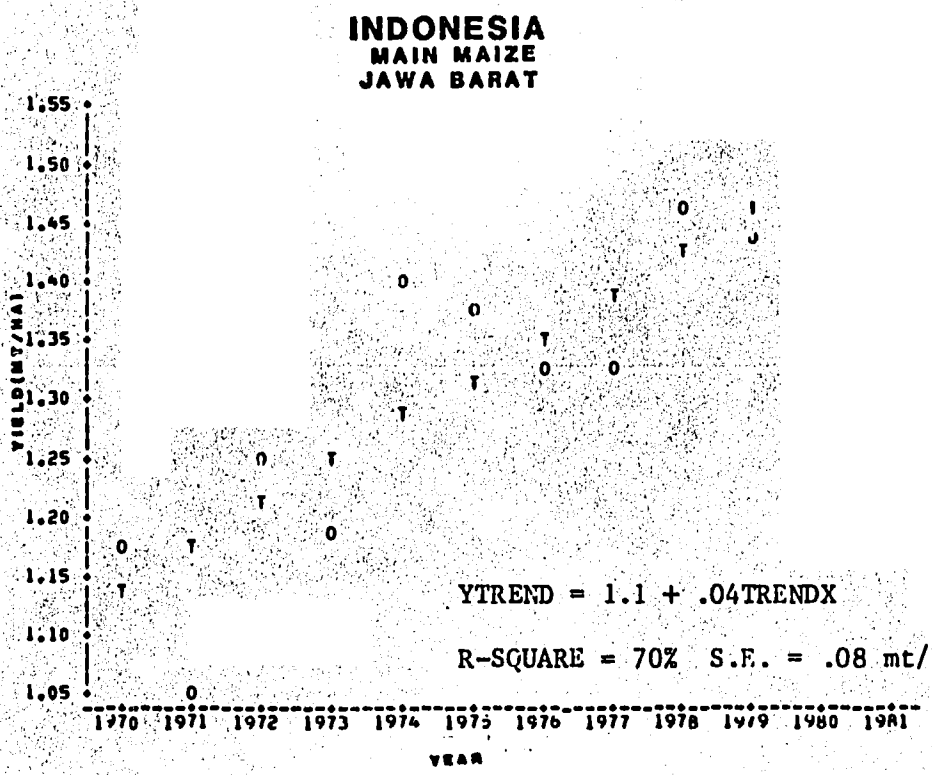
a_i is the ith estimated regression coefficient for the Nth meteorological variable x_i.

Maize Models

Maize data on area, production and yield for the provinces of Jawa Barat, Jawa Timur, Sulawesi Selatan and Sumatra Selatan are shown in Table 5.10. Plots of the yield data are shown in Figures 5.5a-d. Increases in yield over the years can be attributed to high yielding varieties (HYV's) of maize, fertilizers

OBS	PROVINCE	CROP	SEASON	YEAR	AREA	PROD	YIELD
1	JAWA BARAT	MAIZE	MAIN	1968	163778	207157	1.26486
2	JAWA BARAT	MAIZE	MAIN	1969	102193	122045	1.19426
3	JAWA BARAT	MAIZE	MAIN	1970	106559	125652	1.17918
4	JAWA BARAT	MAIZE	MAIN	1971	107986	113547	1.05242
5	JAWA BARAT	MAIZE	MAIN	1972	82868	103276	1.24627
6	JAWA BARAT	MAIZE	MAIN	1973	138972	164746	1.18546
7	JAWA BARAT	MAIZE	MAIN	1974	103362	144946	1.40231
8	JAWA BARAT	MAIZE	MAIN	1975	88074	121124	1.37525
9	JAWA BARAT	MAIZE	MAIN	1976	59635	79305	1.32984
10	JAWA BARAT	MAIZE	MAIN	1977	68833	91356	1.32721
11	JAWA BARAT	MAIZE	MAIN	1978	104967	154128	1.46835
12	JAWA BARAT	MAIZE	MAIN	1979	70091	100548	1.43454
13	JAWA TIMUR	MAIZE	MAIN	1968	1381342	1285529	0.93064
14	JAWA TIMUR	MAIZE	MAIN	1969	1003302	916182	0.91317
15	JAWA TIMUR	MAIZE	MAIN	1970	1318340	1190754	0.90322
16	JAWA TIMUR	MAIZE	MAIN	1971	1156290	1048544	0.90690
17	JAWA TIMUR	MAIZE	MAIN	1972	963901	968502	1.00488
18	JAWA TIMUR	MAIZE	MAIN	1973	1310958	1358153	1.03600
19	JAWA TIMUR	MAIZE	MAIN	1974	1225699	1280373	1.04461
20	JAWA TIMUR	MAIZE	MAIN	1975	1086744	1288774	1.18590
21	JAWA TIMUR	MAIZE	MAIN	1976	859758	1096990	1.27593
22	JAWA TIMUR	MAIZE	MAIN	1977	1098832	1427122	1.29876
23	JAWA TIMUR	MAIZE	MAIN	1978	1224026	1644301	1.34335
24	JAWA TIMUR	MAIZE	MAIN	1979	1097273	1627273	1.48302
25	SULAWESI SELATAN	MAIZE	MAIN	1968	324901	287451	0.88473
26	SULAWESI SELATAN	MAIZE	MAIN	1969	310061	224783	0.72496
27	SULAWESI SELATAN	MAIZE	MAIN	1970	280850	212767	0.75758
28	SULAWESI SELATAN	MAIZE	MAIN	1971	194711	144449	0.74186
29	SULAWESI SELATAN	MAIZE	MAIN	1972	167364	117843	0.70411
30	SULAWESI SELATAN	MAIZE	MAIN	1973	408885	336980	0.82414
31	SULAWESI SELATAN	MAIZE	MAIN	1974	150634	170819	1.13400
32	SULAWESI SELATAN	MAIZE	MAIN	1975	150492	147482	0.98000
33	SULAWESI SELATAN	MAIZE	MAIN	1976	159879	190096	1.18900
34	SULAWESI SELATAN	MAIZE	MAIN	1977	258330	266080	1.03000
35	SULAWESI SELATAN	MAIZE	MAIN	1978	284659	357532	1.25600
36	SULAWESI SELATAN	MAIZE	MAIN	1979	235801	292157	1.23900
37	SUMATRA SELATAN	MAIZE	MAIN	1968	11880	9162	0.77121
38	SUMATRA SELATAN	MAIZE	MAIN	1969	6754	4610	0.68256
39	SUMATRA SELATAN	MAIZE	MAIN	1970	8165	6027	0.73815
40	SUMATRA SELATAN	MAIZE	MAIN	1971	7687	6050	0.78704
41	SUMATRA SELATAN	MAIZE	MAIN	1972	4163	3074	0.73841
42	SUMATRA SELATAN	MAIZE	MAIN	1973	5901	5069	0.85900
43	SUMATRA SELATAN	MAIZE	MAIN	1974	5826	4706	0.80707
44	SUMATRA SELATAN	MAIZE	MAIN	1975	7108	6639	0.93401
45	SUMATRA SELATAN	MAIZE	MAIN	1976	6338	5634	0.88892
46	SUMATRA SELATAN	MAIZE	MAIN	1977	6384	4909	0.76895
47	SUMATRA SELATAN	MAIZE	MAIN	1978	6390	4844	0.75805
48	SUMATRA SELATAN	MAIZE	MAIN	1979	6856	5677	0.82803

TABLE 5.10 Maize Area (Hectares), Production (Tons), and Yield (Tons/Hectare) for Selected Provinces in Indonesia.



E 5.5a Main Season Maize Trend Analysis for Jawa Province, (O = Observed Yield (mt/ha) and T = Trend Value (mt/ha)).

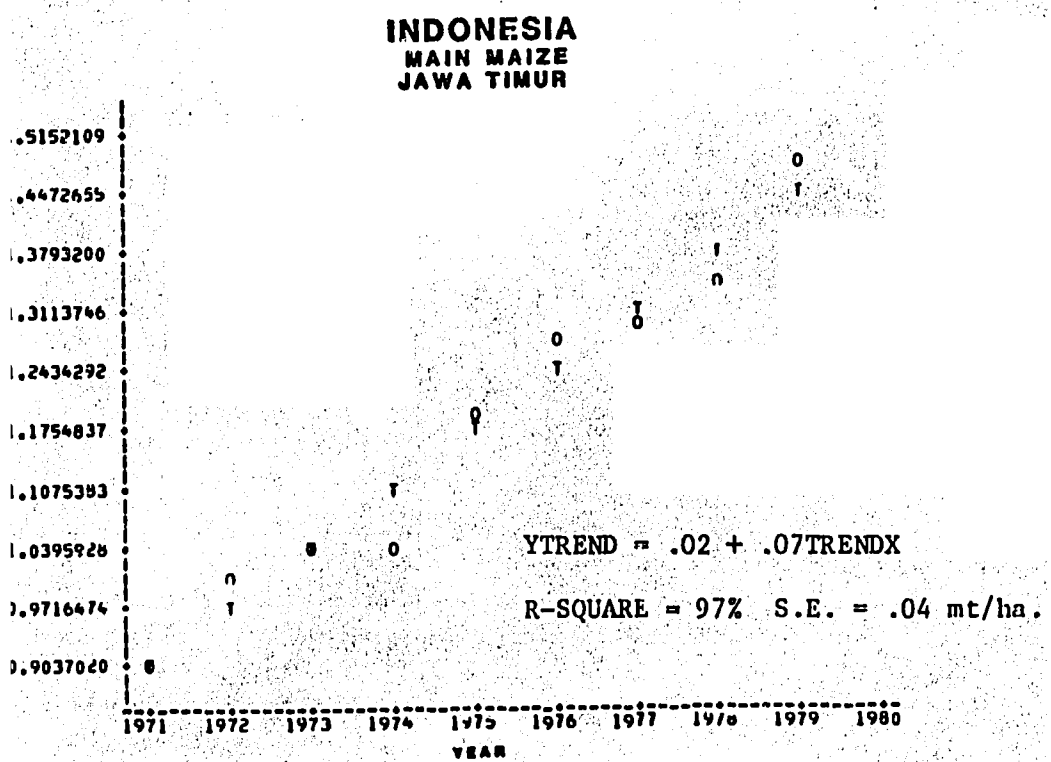


FIGURE 5.5b Main Season Maize Trend Analysis for Jawa Timur Province, (O = Observed Yield (mt/ha) and T = Trend Value (mt/ha)).

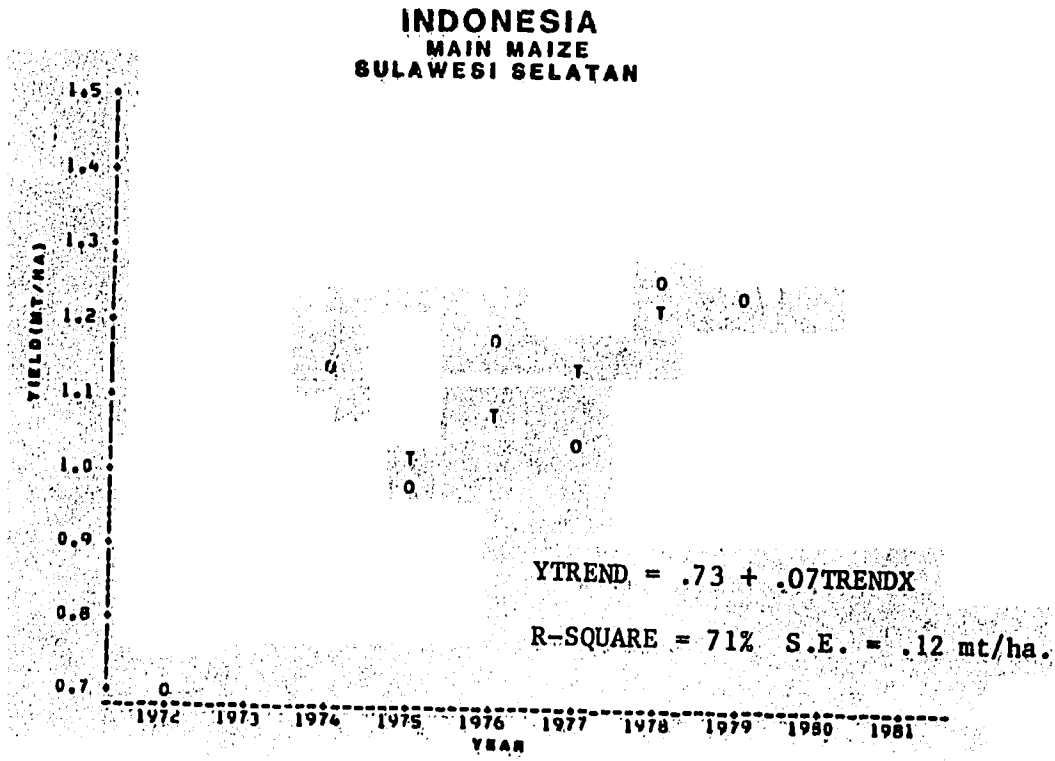


FIGURE 5.5c Main Season Maize Trend Analysis for Sulawesi Selatan Province, (O = Observed Yield (mt/ha) and T = Trend Value (mt/ha)).

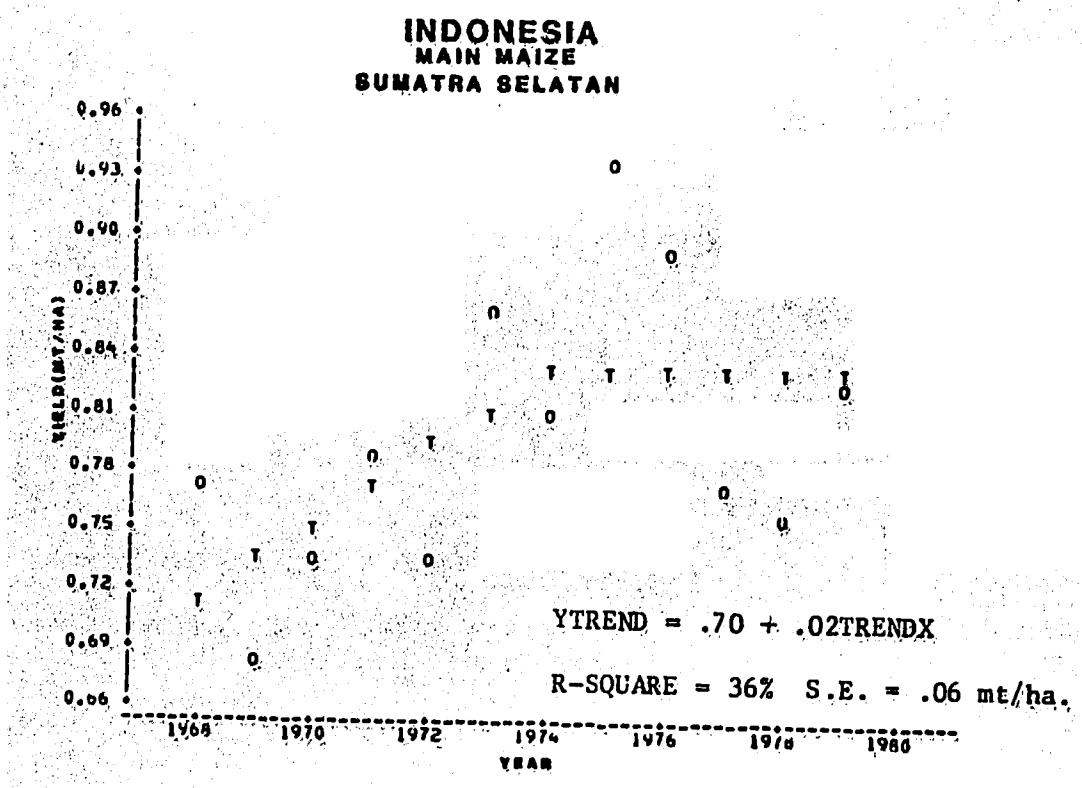


FIGURE 5.5d Main Season Maize Trend Analysis for Sumatra Selatan Province, (O = Observed Yield (mt/ha) and T = Trend Value (mt/ha)).

and improved cultural practices. In each case a linear time trend was fitted to the yield data (Figures 5.5a-d). The variance in yield (R^2) attributed to technology is as follows: i) Jawa Timur-97 percent, ii) Sulawesi Selatan-71 percent, iii) Jawa Barat-70 percent, and iv) Sumatra Selatan-36 percent.

A sample of the input data for modeling maize in Jawa Barat is shown in Table 5.11. Linear correlations between detrended yield and the weather variables for all four provinces are shown in Table 5.12a-d. Monthly as well as cumulative rainfall variables were used in the correlation analyses.

The maize yield data available for modeling includes both the main and secondary season crops. Although maize in Indonesia can be grown throughout the year, the main season maize crop is generally planted during October-November and harvested in January-February. On the other hand, the bulk of the secondary maize crops is generally planted during March-April and harvested in June-July (Table 2.3). For these reasons, the maize yield models developed in this study should be regarded as preliminary and used only for understanding model development.

Table 5.12a shows the correlation analysis for Sulawesi Selatan. Five lagged rainfall variables viz., LP11 (previous November rainfall), LP4 (previous April), LP8_9 (previous August-September), LP9 (previous September) and LP8 (previous August), are significantly correlated. The stepwise regression procedure selected LP11 to be the "best" weather variable for the model (Table 5.13). The model fit is shown in Figure 5.6. The model has an explained variance (R-Square) of 91 percent, out of which trend alone explains 71 percent. An alternative model was also developed for Sulawesi Selatan by forcing the variable LP8_9 (pre-season rainfall) into the model. The resulting model is presented in Table 5.14 and is shown plotted in Figure 5.7.

OBS	COUNTRY	PROVINCE	YEAR	P1	P2	P3	P4	P5	P6
1	INDONESIA	JAWA BARAT	1970	350.000	237.600	463.200	230.400	361.400	265.800
2	INDONESIA	JAWA BARAT	1971	278.800	409.567	334.400	109.600	139.000	106.833
3	INDONESIA	JAWA BARAT	1972	394.000	289.000	269.000	173.143	194.714	16.857
4	INDONESIA	JAWA BARAT	1973	390.833	357.333	311.167	313.833	343.500	201.500
5	INDONESIA	JAWA BARAT	1974	285.714	329.571	235.000	307.429	262.143	102.429
6	INDONESIA	JAWA BARAT	1975	313.714	269.857	266.714	256.429	194.429	71.000
7	INDONESIA	JAWA BARAT	1976	422.000	241.500	191.333	189.667	85.000	55.667
8	INDONESIA	JAWA BARAT	1977	367.500	399.000	469.000	417.000	529.000	280.000
9	INDONESIA	JAWA BARAT	1978	309.000	241.667	332.667	177.667	233.333	323.333
10	INDONESIA	JAWA BARAT	1979	382.000	440.000	332.500	391.500	437.000	178.500
11	INDONESIA	JAWA BARAT	1980	346.333	294.333	258.333	293.667	187.000	96.333

OBS	P7	P8	P9	P10	P11	P12	CROP	SEASON	AREA
1	123.400	39.800	78.200	218.800	429.000	388.400	MAIZE	MAIN	105559
2	63.500	51.833	135.667	382.200	383.000	320.167	MAIZE	MAIN	107986
3	5.000	37.000	5.333	46.667	177.667	323.333	MAIZE	MAIN	82668
4	175.600	169.000	426.000	368.667	381.667	275.500	MAIZE	MAIN	133972
5	135.000	226.286	389.429	309.286	449.285	275.285	MAIZE	MAIN	103362
6	160.143	108.571	359.429	510.714	295.285	427.714	MAIZE	MAIN	83074
7	44.500	81.000	37.667	344.333	539.667	455.167	MAIZE	MAIN	59635
8	44.000	88.500	124.000	348.000	492.000	350.500	MAIZE	MAIN	68833
9	185.667	262.667	308.333	369.000	307.000	390.000	MAIZE	MAIN	104967
10	125.000	157.000	271.500	288.500	477.000	267.500	MAIZE	MAIN	70691
11	116.333	220.667	188.667	284.000	342.333	342.667	MAIZE	MAIN	.

OBS	PROD	YIELD	I	LP1	L 2	LP3	LP4	LP5	LP6
1	125652	1.17918	13	267.667	238.600	244.200	411.600	180.200	115.000
2	113647	1.05242	13	350.000	237.600	463.200	230.400	361.400	265.800
3	103276	1.24627	13	278.800	409.667	334.400	109.600	139.000	106.833
4	164746	1.18546	13	394.000	289.000	269.000	173.143	194.714	16.857
5	144946	1.40231	13	390.833	357.333	311.167	313.833	343.500	201.500
6	121124	1.37525	13	285.714	329.571	235.000	307.429	262.143	102.429
7	79305	1.32994	13	313.714	269.857	266.714	256.429	194.429	71.000
8	91356	1.32721	13	422.000	241.500	191.333	189.667	85.000	55.667
9	154128	1.46835	13	367.500	399.000	469.000	417.000	529.000	280.000
10	100546	1.43454	13	308.000	241.667	332.667	177.667	233.333	323.333
11	.	.	13	382.000	440.000	332.500	391.500	437.000	178.500

OBS	LP7	LP8	LP9	LP10	LP11	LP12	WPCP	LP11_1	LP11_2
1	38.500	15.333	163.333	196.400	285.600	242.200	1809.00	877.50	1115.40
2	123.400	39.800	78.200	218.800	429.000	388.400	1949.97	1096.20	1505.87
3	63.500	51.833	135.667	382.200	383.000	320.167	1832.31	1101.17	1390.17
4	5.000	37.000	5.333	46.667	177.667	323.333	1874.17	891.53	1249.17
5	175.600	169.000	426.000	368.667	381.667	275.500	1814.88	942.88	1272.45
6	135.000	226.286	389.429	309.286	449.285	275.285	1831.29	1038.29	1399.14
7	160.143	108.571	359.429	510.714	295.285	427.714	1767.50	1145.00	1386.50
8	44.500	81.000	37.667	344.333	539.667	455.167	2647.33	1362.33	1761.33
9	44.000	88.500	124.000	348.000	492.000	350.500	1902.50	1150.50	1392.17
10	185.667	262.667	308.333	369.000	307.000	390.000	2243.00	1079.00	1519.00
11	125.000	157.000	271.500	288.500	477.000	267.500	1947.17	1090.53	1385.17

OBS	LP11_3	P1_2	P1_3	P1_4	P2_3	P2_4	P2_5	P2_6	P2_7
1	1578.60	587.600	1050.80	1281.20	700.80	931.20	1292.60	1558.40	1681.80
2	1840.27	688.467	1022.87	1132.47	744.07	853.67	992.67	1099.50	1163.00
3	1659.17	687.000	956.00	1129.14	554.00	731.14	929.86	946.71	951.71
4	1560.33	748.167	1059.33	1373.17	668.57	992.33	1325.83	1527.33	1702.93
5	1547.45	615.286	850.29	1157.71	564.57	872.00	1134.14	1236.57	1371.57
6	1574.85	563.571	850.29	1106.71	536.57	743.00	987.43	1058.43	1218.57
7	1577.83	663.500	854.83	1044.50	432.83	622.50	704.50	764.17	808.67
8	2230.33	766.500	1235.50	1652.50	868.00	1285.00	1614.00	2094.00	2130.00
9	1724.83	549.667	882.33	1060.00	574.33	752.00	985.33	1308.57	1494.33
10	1651.50	822.000	1154.50	1545.00	772.50	1164.00	1601.00	1779.50	1904.50
11	1653.50	640.667	909.00	1202.67	562.67	856.33	1043.33	1139.57	1256.00

OBS	P3_4	P3_5	P3_6	P3_7	P4_5	P4_6	P4_7	LP4_7	LP8_9
1	693.60	1055.00	1320.80	1444.20	591.80	857.60	981.00	745.50	178.667
2	444.00	583.00	689.83	753.33	248.60	355.43	414.93	981.00	118.000
3	443.14	640.86	657.71	662.71	371.85	388.71	393.71	418.93	167.500
4	625.00	968.50	1170.00	1345.60	657.33	858.83	1034.43	393.71	42.333
5	542.43	804.57	907.00	1042.00	569.57	672.00	807.00	1034.43	595.000
6	523.14	717.57	788.57	948.71	450.85	521.85	682.00	807.00	615.714
7	381.00	467.00	522.67	567.17	275.67	331.33	375.33	682.00	468.000
8	845.00	1415.00	1645.00	1719.00	946.00	1226.00	1270.00	375.33	118.667
9	510.33	743.67	1067.00	1252.67	411.00	734.33	920.00	1270.00	212.500
10	724.00	1161.00	1339.50	1464.50	828.50	1007.00	1132.00	920.00	571.000
11	582.00	749.00	845.33	961.67	480.67	577.00	693.33	1132.00	428.500

OBS	LP8_10	LP8_11	LP8_12	LP8_1	LP8_2	LP8_3	LP4_1	TM	TRENDX
1	375.067	660.67	902.87	1252.87	1490.47	1953.67	2698.97	828.59	1
2	336.500	765.80	1154.20	1433.00	1842.67	2177.07	3158.07	349.19	2
3	564.700	952.70	1272.87	1670.87	1959.87	2228.87	2647.80	302.40	3
4	83.000	266.67	590.00	980.83	1338.17	1649.33	2043.05	839.24	4
5	963.667	1345.33	1620.83	1906.55	2236.12	2471.12	3505.55	631.45	5
6	924.000	1373.29	1648.57	1962.29	2232.14	2498.86	3305.86	526.50	6
7	978.714	1274.00	1701.71	2123.71	2385.21	2556.55	3238.55	288.61	7
8	503.000	1042.67	1497.83	1865.33	2264.33	2733.33	3109.17	1047.70	8
9	560.500	1052.50	1403.00	1711.00	1952.67	2285.33	3555.33	792.57	9
10	940.000	1247.00	1637.00	2019.00	2459.00	2791.50	3711.50	907.10	10
11	717.000	1194.00	1461.50	1807.83	2102.17	2370.50	3502.50	538.23	11

TABLE 5.11 Input Data for Modeling Main Season Maize in Jawa Barat Province in Indonesia.

COUNTRY=INDONESIA PROVINCE=SULAWESI SELATAN CROP=MAIZE SEASON=MAIN

CORRELATION COEFFICIENTS / PROB > IRI UNDER HO:RHO=0
/ NUMBER OF OBSERVATIONS

DTYIELD

LP11	LP4	LP8_9	LP9	P5	P1	P4	LP2
0.83223	0.75631	0.73727	0.70630	0.67129	-0.63761	-0.63633	-0.61492
0.0104	0.0299	0.0369	0.0502	0.0583	0.0890	0.0898	0.1417
8	8	8	8	8	8	8	7
LP8_11	P10	LP4_7	LP4_7	P4_5	LP8_12	P4_6	P2_3
0.60684	0.59496	0.56635	0.56635	-0.54270	0.52446	-0.49863	0.47700
0.1107	0.1197	0.1433	0.1433	0.1646	0.1821	0.2085	0.2320
8	8	8	8	8	8	8	8
P12	P3	P2	P1_4	P5	P4_7	LP7	YMI
0.47692	0.42689	0.39516	-0.37663	0.37511	-0.35181	0.33920	-0.31082
0.2321	0.2915	0.3326	0.3578	0.3599	0.3928	0.4111	0.4537
8	8	8	8	8	8	8	8
LP11_3	LP8_3	P7	P3_6	P3_4	P1_2	P3_5	LP8_2
0.29373	0.29016	0.27213	-0.26022	-0.25580	-0.24638	-0.23230	0.23018
0.4801	0.4857	0.5144	0.5337	0.5393	0.5564	0.5799	0.5834
8	8	8	8	8	8	8	8
P9	LP11_2	P6	LP6	LP8_10	LP10	P3_7	P11
0.22292	0.21674	-0.21521	-0.20154	0.19547	-0.18564	-0.15370	0.14964
0.5957	0.6070	0.6088	0.6322	0.6445	0.6598	0.7163	0.7236
8	8	8	8	8	8	8	8
LP8_1	P1_3	NWPCP	P2_7	P2_4	P2_5	LP1	P8
0.13476	-0.11919	0.10863	0.10659	0.10196	0.09732	-0.09090	0.08580
0.7504	0.7786	0.7979	0.8017	0.8101	0.8187	0.8305	0.8399
8	8	8	8	8	8	8	8
LP12	LP11_1	LP3	P2_6	P5			
0.07939	0.07899	-0.06679	0.04756	-0.01396			
0.8518	0.8525	0.8751	0.9110	0.9738			
8	8	8	8	8			

TABLE 5.12a Detrended Yield Versus Weather Correlations for the Main Season Maize Crop in Sulawesi Selatan Province.

COUNTRY=INDONESIA PROVINCE=JAWA BARAT CROP=MAIZE SEASON=MAIN

CORRELATION COEFFICIENTS / PROB > IRI UNDER HO:RHO=0
/ NUMBER OF OBSERVATIONS

DTYIELD

LP12	LP2	P1_2	LP9	P1_3	P2	LP11_3	LP11_2
-0.70430	0.64894	-0.64181	0.60652	-0.60454	-0.59271	-0.56922	-0.55535
0.0230	0.0423	0.0454	0.0630	0.0641	0.0710	0.0859	0.0956
10	10	10	10	10	10	10	10
P2_3	LP8_9	LP8_10	LP4	LP8_11	NWPCP	P1_4	LP11_1
-0.53869	0.53183	0.48777	0.48565	0.45738	-0.45083	-0.38810	-0.37125
0.1081	0.1136	0.1527	0.1547	0.1838	0.1910	0.2678	0.2909
10	10	10	10	10	10	10	10
P8	P2_4	P7	LP4_7	LP4_7	LP8	LP8_12	P3
0.36347	-0.34821	0.31335	0.31010	0.31010	0.30699	0.30265	-0.28269
0.3019	0.3241	0.3780	0.3832	0.3832	0.3882	0.3953	0.4287
10	10	10	10	10	10	10	10
P11	LP8_1	LP1	P2_5	LP10	P9	P2_6	P1
-0.27646	0.27166	-0.27070	-0.26139	0.25790	0.24703	-0.24617	-0.23093
0.4394	0.4477	0.4494	0.4657	0.4719	0.4914	0.4930	0.5209
10	10	10	10	10	10	10	10
LP5	P10	P2_7	LP7	P3_4	P3_6	LP8_2	P3_5
0.21910	-0.20191	-0.19014	0.16986	-0.16146	-0.14748	0.14558	-0.14485
0.5431	0.5759	0.5988	0.6390	0.6559	0.6843	0.6882	0.6897
10	10	10	10	10	10	10	10
P12	LP3	P5	P6	P4_6	P3_7	LP8_3	P4_5
0.12949	-0.12573	-0.12477	-0.11622	-0.09715	-0.08961	0.08188	-0.07345
0.7215	0.7293	0.7313	0.7492	0.7995	0.8055	0.8221	0.8402
10	10	10	10	10	10	10	10
LP11	YMI	LP6	P4_7	P4			
0.07108	-0.04591	0.03781	-0.02931	0.00374			
0.8453	0.8998	0.9174	0.9359	0.9918			
10	10	10	10	10			

TABLE 5.12b Detrended Yield Versus Weather Correlations for the Main Season Maize Crop in Jawa Barat Province.

COUNTRY=INDONESIA PROVINCE=JAWA TIMUR CROP=MAIZE SEASON=MAIN

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0
/ NUMBER OF OBSERVATIONS

DTYIELD

P12	P2	LP8_1	LP8_12	P2	LP11_1	P1_2	P8
-0.51507	-0.47082	0.46969	0.46834	0.44525	0.44485	-0.44277	-0.42170
0.1559	0.2390	0.2021	0.2036	0.2577	0.2302	0.2719	0.2583
9	8	9	9	8	9	8	9
LP10	P9	LP12	LP8_11	LP8_10	LP7	P11	LP5
0.41961	-0.41370	0.39859	0.39839	0.39535	-0.38112	-0.34888	0.34523
0.2509	0.3083	0.2880	0.2882	0.2923	0.3115	0.3575	0.3629
9	8	9	9	9	9	9	9
LP11	P10	P1_3	LP8	P7	P2_3	P6	LP4
0.31369	-0.30042	-0.27972	0.27936	-0.27239	-0.27231	-0.25908	-0.25009
0.4111	0.4322	0.5022	0.4666	0.4783	0.5141	0.5008	0.5163
9	9	8	9	9	8	9	9
P1_4	P2_4	LP8_9	P1	LP11_2	LP9	LP3	P5
-0.23136	-0.22852	0.22356	-0.19661	-0.18056	0.17505	-0.15144	0.14459
0.5814	0.5862	0.5631	0.6122	0.6587	0.6524	0.7204	0.7105
8	8	9	9	8	9	8	9
NWPCP	P2_5	P2_7	LP8_3	P1	P2_6	LP11_3	YMI
-0.12486	-0.12482	-0.11638	0.11401	0.11133	-0.10893	-0.10800	-0.10671
0.7683	0.7684	0.7838	0.7881	0.7755	0.7974	0.7991	0.7847
8	8	8	8	9	8	8	9
P3	LP8_2	P4_7	P4_5	P3_6	LP4_7	LP4_7	P3_5
0.10458	0.09297	-0.08823	0.08717	0.04527	-0.04137	-0.04137	0.04098
0.8053	0.8267	0.8214	0.8235	0.9152	0.9158	0.9158	0.9233
8	8	9	9	8	9	9	8
P4_6	P3_4	LP6	P3_7	P4			
-0.03617	-0.03533	0.03073	0.01584	0.00586			
0.9264	0.9338	0.9374	0.9703	0.9881			
9	8	9	8	9			

TABLE 5.12c Detrended Yield Versus Weather Correlations for the Main Season Maize Crop in Jawa Timur Province.

COUNTRY=INDONESIA PROVINCE=SUMATRA SELATAN CROP=MAIZE SEASON=MAIN

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0
/ NUMBER OF OBSERVATIONS

DTYIELD

P3	P12	LP11_2	LP2	P2	LP11	P3_4	LP5
0.72311	-0.68973	-0.47714	0.46632	-0.46587	-0.45768	0.44838	-0.39662
0.0079	0.0131	0.1378	0.1265	0.1269	0.1569	0.1438	0.2018
12	12	11	12	12	11	12	12
LP6	LP8	P8	LP8_2	P1_2	P4	LP8_12	NWPCP
-0.39361	-0.37377	0.35387	-0.32941	-0.31627	-0.27437	-0.27018	-0.25652
0.2055	0.2314	0.2591	0.3226	0.3166	0.3881	0.4217	0.4282
12	12	12	11	12	12	11	11
LP11_1	LP8_11	P3_5	LP4_7	LP4_7	LP8_1	LP8_9	LP7
-0.24809	-0.24080	0.23751	-0.22665	-0.22565	-0.22098	-0.21412	0.21194
0.4620	0.4757	0.4573	0.4787	0.4787	0.5138	0.5040	0.5084
11	11	12	12	12	11	12	12
LP4	P6	LP11_3	P2_4	LP8_3	P2_6	P4_6	P1
-0.19271	-0.18394	-0.16999	-0.16415	-0.15156	-0.14787	-0.14313	0.14176
0.5485	0.5671	0.6173	0.6102	0.6564	0.6465	0.6572	0.6603
12	12	11	12	11	12	12	12
P9	P3_6	P2_7	P2_5	P4_5	P4_7	P10	YMI
0.13594	0.12941	-0.12177	-0.12014	-0.11813	-0.11548	0.11170	-0.11114
0.6736	0.6885	0.7062	0.7099	0.7146	0.7208	0.7296	0.7310
12	12	12	12	12	12	12	12
LP12	LP9	P11	P3_7	P3	P1_3	LP8_10	LP1
-0.10288	0.09994	0.09900	0.09640	-0.08562	0.07805	-0.06877	0.05681
0.7634	0.7573	0.7595	0.7657	0.7889	0.8095	0.8408	0.8608
11	12	12	12	12	12	11	12
P2_3	P1_4	P5	LP10	P7			
-0.04040	-0.03835	0.01696	-0.01214	-0.01184			
0.9008	0.9058	0.9583	0.9717	0.9709			
12	12	12	11	12			

TABLE 5.12d Detrended Yield Versus Weather Correlations for the Main Season Maize Crop in Sumatra Selatan Province.

INDONESIA
MAIN SEASON MAIZE YIELD MODEL
SULAWESI SELATAN

MODEL: MODEL01		SSE	0.024561	F RATIO	26.03
		DFE	5	PROB>F	0.0023
DEP VAR: YIELD		MSE	0.004912242	R-SQUARE	0.9124

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	0.599458	0.067592	8.8557	0.0003
TRENDX	1	0.068326	0.010817	6.3166	0.0015
LP11	1	0.0003845149	0.0001144868	3.3586	0.0201

TABLE 5.13 Main Season Maize Yield Model for Sulawesi Selatan Using a Linear Trend (TRENDX) and Previous November Rainfall (LP_{11})

MAIN SEASON MAIZE YIELD MODEL
SULAWESI SELATAN

MODEL: MODEL01		SSE	0.035661	F RATIO	17.15
		DFE	5	PROB>F	0.0058
DEP VAR: YIELD		MSE	0.007132124	R-SQUARE	0.8728

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	0.620849	0.079596	7.7707	0.0006
TRENDX	1	0.073572	0.013157	5.5920	0.0025
LP8_9	1	0.0007606457	0.0003051643	2.4926	0.0550

TABLE 5.14 Alternate Main Season Maize Yield Model for Sulawesi Selatan Using a Linear Trend (TRENDX) and Previous August-September Rainfall (LP8_9).

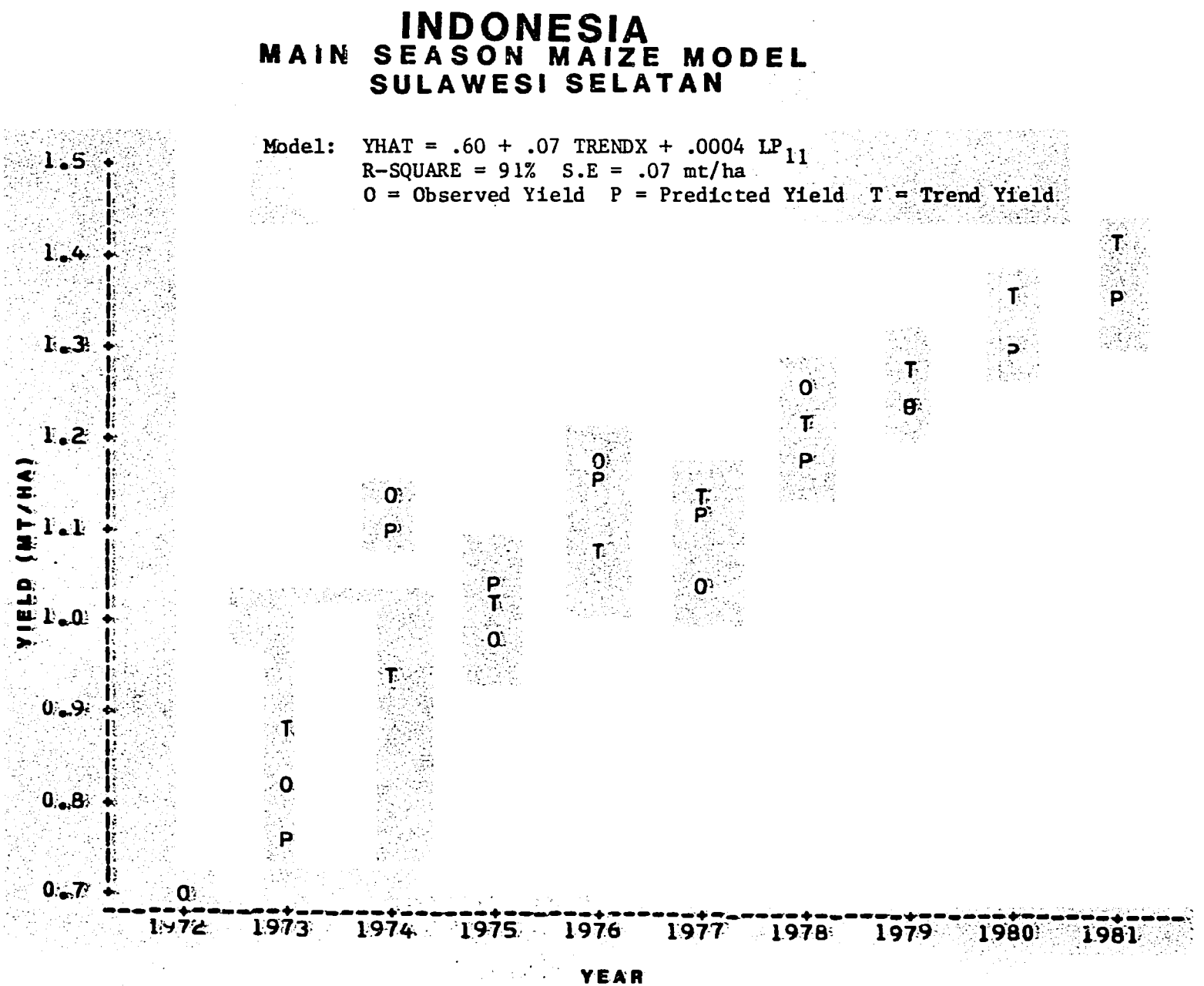


FIGURE 5.6 Main Season Maize Yield Model Plot for Sulawesi Selatan Using a Linear Trend (TRENDX) and Previous November Rainfall (LP..).

INDONESIA
MAIN SEASON MAIZE MODEL
SULAWESI SELATAN

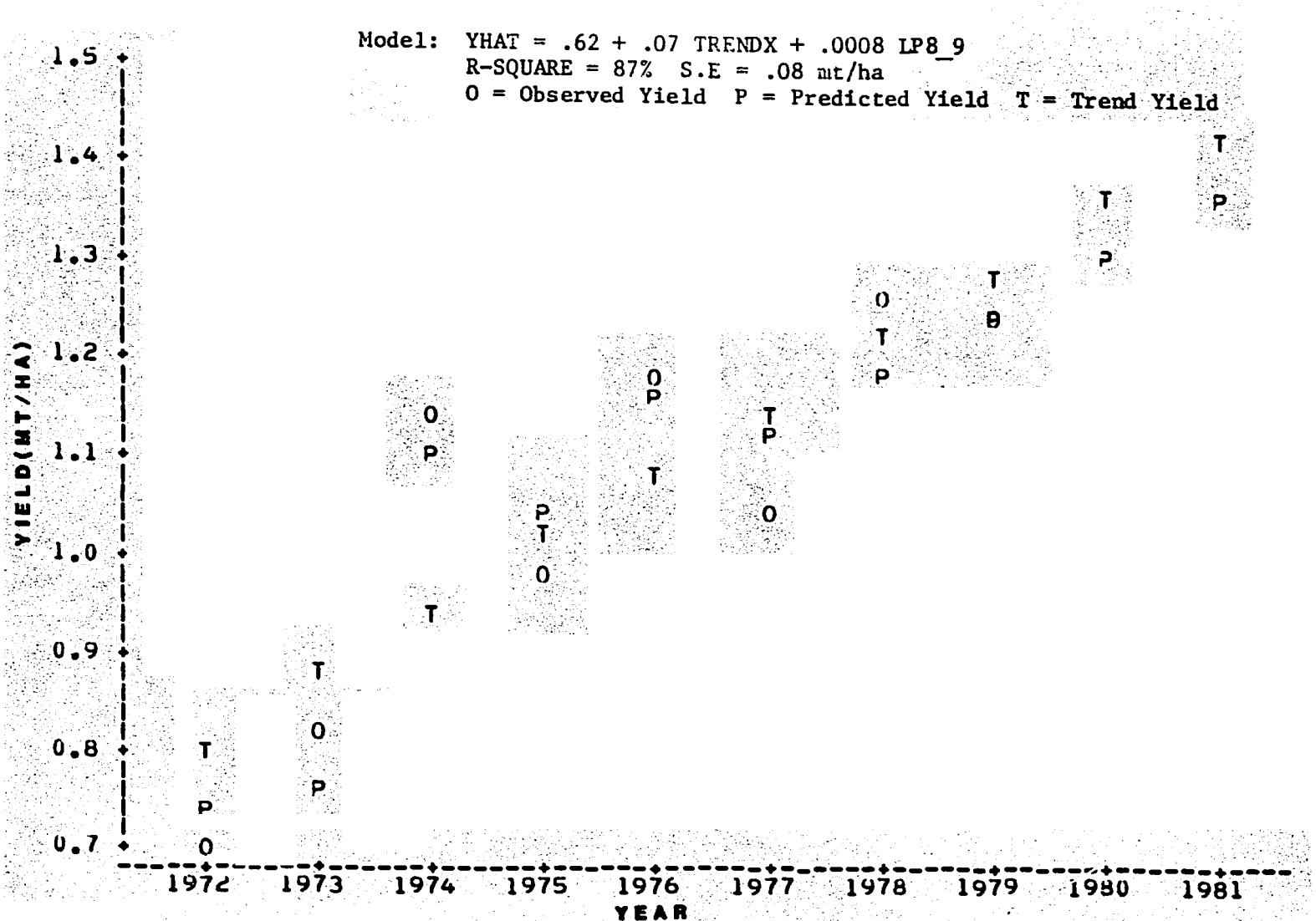


FIGURE 5.7 Alternate Main Season Yield Model Plot for Sulawesi Selatan Using a Linear Trend (TRENDX) and Previous August-September Rainfall (LP8_9).

The correlation analysis for Jawa Barat (Table 5.12b) indicates that only two variables, LP2 (previous February rainfall) and LP9 (previous September rainfall), to be significantly correlated with the detrended yield. The variable LP9 alone was entered into the regression analysis as it was physiologically more meaningful than LP2. The regression analysis is presented in Table 5.15 and the model plot is shown in Figure 5.8. The model has an R-Square value of 82 percent; trend alone explains 70 percent of the yield variability.

Table 5.12c shows the correlation analysis for Jawa Timur. It should be recalled that trend for this province explains 97 percent of the variability in yield about it mean value. For this season no meaningful correlations were found in the analysis.

The correlation analysis for Sumatra Selatan is shown in Table 5.12d. Rainfall during planting in March (P3) appears to be the only significant weather variable. The regression analysis is presented in Table 5.16 and the model plot is shown in Figure 5.9. The model has an explained variance (R-Square) of 70 percent. Trend alone explains 36 percent of the variability yield.

Rice Models

The dryland paddy area, production and yield data for the provinces of Jawa Barat, Jawa Timur, Lampung, Nusa Tenggara Barat, Sulawesi Selatan and Sumatra Selatan are shown in Table 5.17. Plots of the yield data are shown in Figures 5.10a-f. In all six cases, a significant drop in yield from 1976 onwards is evident. Table 5.17 suggests that this reduction in yield is due to a drop in production and not due to an increase in area. Higher fertilizer prices may also have contributed to overall reductions in yield.

The dryland paddy crop is generally cultivated during the main rainy season and is not irrigated. Planting generally takes place during October-November

INDONESIA
MAIN SEASON MAIZE YIELD MODEL
JAWA BARAT

MODEL: MODEL01		SSE	0.028042	F RATIO	15.98
		DFE	7	PROB>F	0.0025
DEP VAR: YIELD		MSE	0.004005961	R-SQUARE	0.8204

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	1.059973	0.047023	22.5414	0.0001
TRENDX	1	0.032536	0.007210408	4.5124	0.0028
LP9	1	0.0003016796	0.0001414475	2.1328	0.0704

TABLE 5.15 Main Season Maize Yield Model for Jawa Barat Using a Linear Trend (TRENDX) and Previous September Rainfall (LP_9).

MAIN SEASON MAIZEYIELD MODEL
SUMATRA SELATAN

MODEL: MODEL01		SSE	0.016749	F RATIO	10.33
		DFE	9	PROB>F	0.0047
DEP VAR: YIELD		MSE	0.001860972	R-SQUARE	0.6965

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	0.535989	0.060715	8.8280	0.0001
TRENDX	1	0.019811	0.005859911	3.3809	0.0081
P3	1	0.0006188995	0.0001968495	3.1440	0.0119

TABLE 5.16 Main Season Maize Yield Model for Sumatra Selatan Using a Linear Trend (TRENDX) and March Rainfall (P_3).

INDONESIA
MAIN SEASON MAIZE MODEL
JAWA BARAT

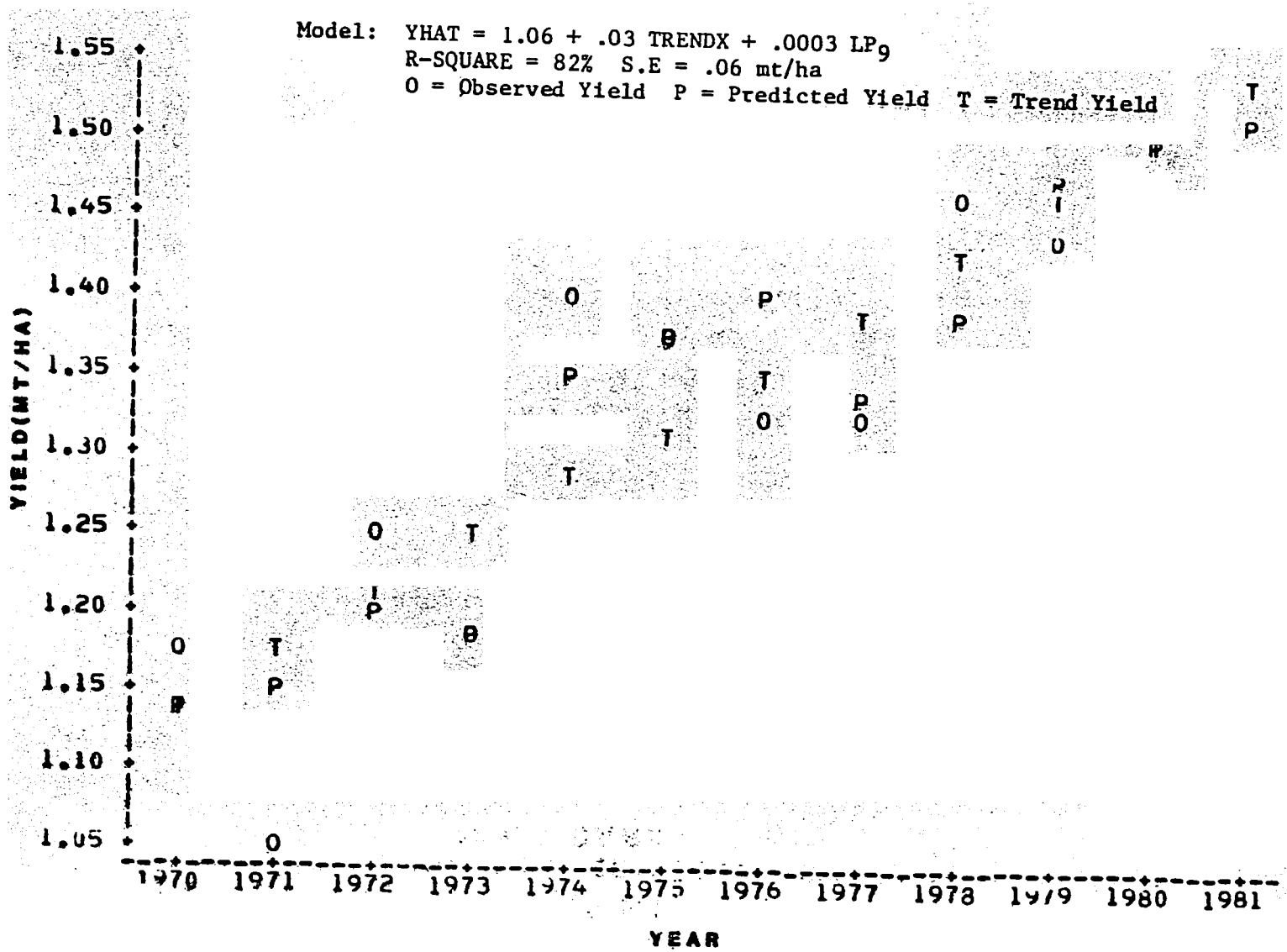


FIGURE 5.8 Main Season Maize Yield Model Plot for Jawa Barat Using a Linear Trend (TRENDX) and Previous September Rainfall (LP9)

INDONESIA
MAIN SEASON MAIZE MODEL
SUMATRA SELATAN

Model: YHAT = .54 + .02 TRENDX + .0006 P_3
R-SQUARE = 70% S.E = .04 mt/ha
O = Observed Yield P = Predicted Yield T = Trend Yield

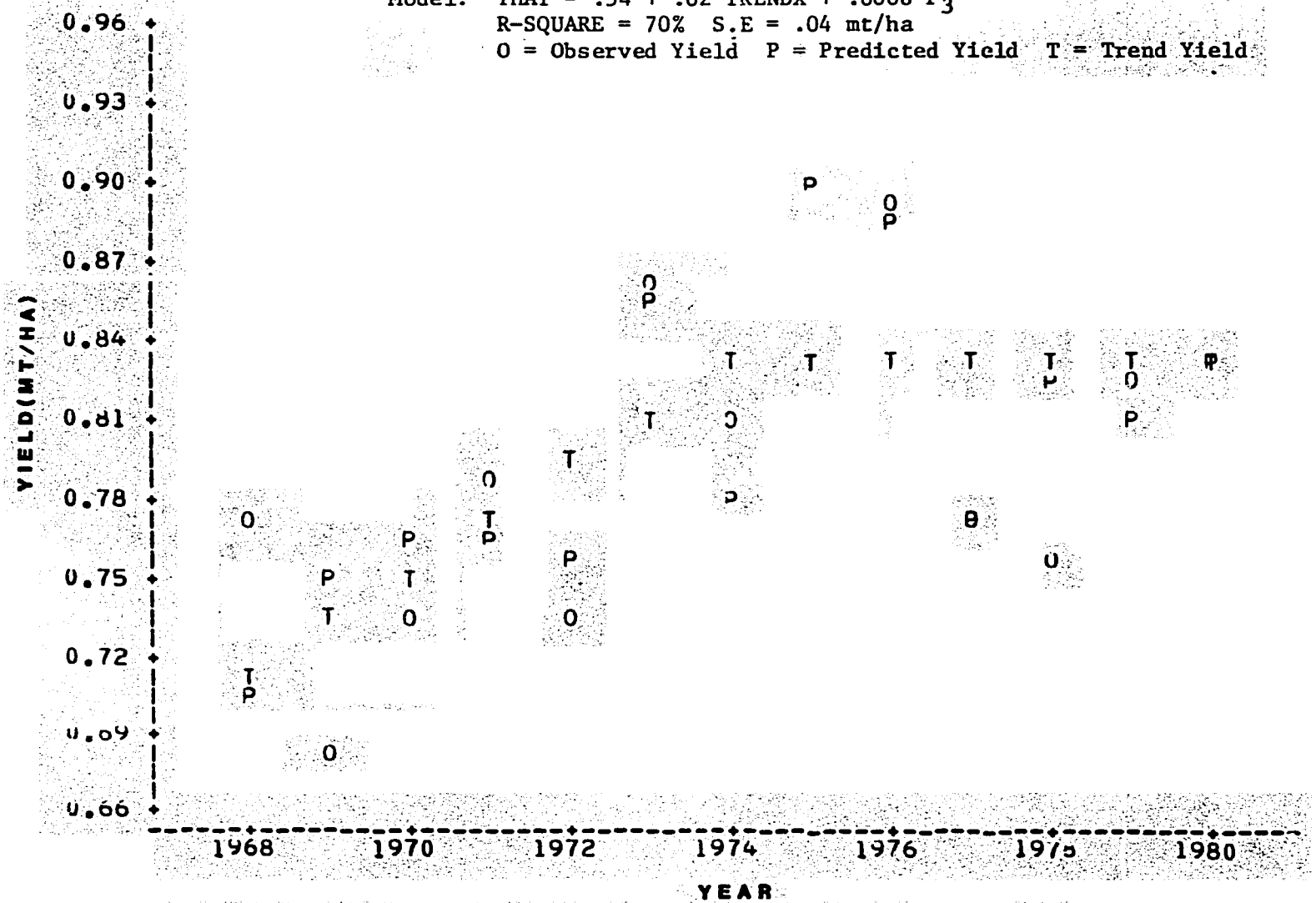


FIGURE 5.9 Main Season Maize Yield Model Plot for Sumatra Selatan Using a Linear Trend (TRENDX) and March Rainfall (P3).

OBS	REGION	CROP	SEASON	AREA	PROD	YIELD
1	JAWA BARAT	PADDY	DRYLAND	217552	292326	1.34371
2	JAWA BARAT	PADDY	DRYLAND	183697	269254	1.46581
3	JAWA BARAT	PADDY	DRYLAND	187694	288829	1.53883
4	JAWA BARAT	PADDY	DRYLAND	195175	278107	1.42522
5	JAWA BARAT	PADDY	DRYLAND	162898	271057	1.66397
6	JAWA BARAT	PADDY	DRYLAND	163045	251034	1.53966
7	JAWA BARAT	PADDY	DRYLAND	129962	209933	1.61534
8	JAWA BARAT	PADDY	DRYLAND	108340	190696	1.76016
9	JAWA BARAT	PADDY	DRYLAND	102091	144633	1.41671
10	JAWA BARAT	PADDY	DRYLAND	114001	176104	1.54476
11	JAWA BARAT	PADDY	DRYLAND	128516	190919	1.48557
12	JAWA BARAT	PADDY	DRYLAND	97778	149192	1.52582
13	JAWA TIMUR	PADDY	DRYLAND	77114	106823	1.38526
14	JAWA TIMUR	PADDY	DRYLAND	75146	127879	1.70174
15	JAWA TIMUR	PADDY	DRYLAND	65069	108008	1.65990
16	JAWA TIMUR	PADDY	DRYLAND	72081	122843	1.70424
17	JAWA TIMUR	PADDY	DRYLAND	72182	125042	1.73232
18	JAWA TIMUR	PADDY	DRYLAND	75974	158819	2.09044
19	JAWA TIMUR	PADDY	DRYLAND	60381	107018	1.77238
20	JAWA TIMUR	PADDY	DRYLAND	65419	112982	1.72705
21	JAWA TIMUR	PADDY	DRYLAND	61098	78131	1.27911
22	JAWA TIMUR	PADDY	DRYLAND	57649	74846	1.29831
23	JAWA TIMUR	PADDY	DRYLAND	61012	80974	1.32718
24	JAWA TIMUR	PADDY	DRYLAND	59188	84192	1.42245
25	LAMPUNG	PADDY	DRYLAND	170417	219848	1.29006
26	LAMPUNG	PADDY	DRYLAND	138908	144122	1.03754
27	LAMPUNG	PADDY	DRYLAND	139768	180428	1.29091
28	LAMPUNG	PADDY	DRYLAND	144673	197095	1.36235
29	LAMPUNG	PADDY	DRYLAND	143138	207436	1.44920
30	LAMPUNG	PADDY	DRYLAND	128414	206899	1.61119
31	LAMPUNG	PADDY	DRYLAND	111831	175656	1.57100
32	LAMPUNG	PADDY	DRYLAND	103740	194305	1.87300
33	LAMPUNG	PADDY	DRYLAND	107332	135453	1.26200
34	LAMPUNG	PADDY	DRYLAND	112834	173313	1.53600
35	LAMPUNG	PADDY	DRYLAND	128816	195414	1.51700
36	LAMPUNG	PADDY	DRYLAND	113681	176319	1.55100
37	NUSA TENGGARA BARAT	PADDY	DRYLAND	28004	48264	1.72418
38	NUSA TENGGARA BARAT	PADDY	DRYLAND	19727	31238	1.58351

TABLE 5.17 Area (Hectares), Production (Metric Tons) and Yield (MT/HA) Statistics for Dryland Paddy Rice in Selected Provinces of Indonesia.

OBS	REGION	CROP	SEASON	AREA	PROD	YIELD
39	NUSA TENGGARA BARAT	PADDY	DRYLAND	19430	31804	1.63685
40	NUSA TENGGARA BARAT	PADDY	DRYLAND	21973	29054	1.32362
41	NUSA TENGGARA BARAT	PADDY	DRYLAND	15726	22180	1.41040
42	NUSA TENGGARA BARAT	PADDY	DRYLAND	22012	35201	1.59917
43	NUSA TENGGARA BARAT	PADDY	DRYLAND	18207	26855	1.47498
44	NUSA TENGGARA BARAT	PADDY	DRYLAND	16056	26878	1.67402
45	NUSA TENGGARA BARAT	PADDY	DRYLAND	14274	17314	1.21297
46	NUSA TENGGARA BARAT	PADDY	DRYLAND	14614	18852	1.29000
47	NUSA TENGGARA BARAT	PADDY	DRYLAND	20646	25126	1.21699
48	NUSA TENGGARA BARAT	PADDY	DRYLAND	14551	18465	1.26898
49	SULAWESI SELATAN	PADDY	DRYLAND	50414	77732	1.54187
50	SULAWESI SELATAN	PADDY	DRYLAND	50610	68498	1.35345
51	SULAWESI SELATAN	PADDY	DRYLAND	49840	65777	1.31976
52	SULAWESI SELATAN	PADDY	DRYLAND	41754	61561	1.47437
53	SULAWESI SELATAN	PADDY	DRYLAND	20 03	27358	1.33646
54	SULAWESI SELATAN	PADDY	DRYLAND	36099	54326	1.50492
55	SULAWESI SELATAN	PADDY	DRYLAND	20200	29048	1.43802
56	SULAWESI SELATAN	PADDY	DRYLAND	19623	30730	1.56602
57	SULAWESI SELATAN	PADDY	DRYLAND	19319	24573	1.27300
58	SULAWESI SELATAN	PADDY	DRYLAND	23362	28351	1.21398
59	SULAWESI SELATAN	PADDY	DRYLAND	30998	36249	1.17101
60	SULAWESI SELATAN	PADDY	DRYLAND	33044	42627	1.29001
61	SUMATRA SELATAN	PADDY	DRYLAND	199882	249508	1.24828
62	SUMATRA SELATAN	PADDY	DRYLAND	156884	203081	1.29447
63	SUMATRA SELATAN	PADDY	DRYLAND	152003	206871	1.36097
64	SUMATRA SELATAN	PADDY	DRYLAND	150647	185750	1.23321
65	SUMATRA SELATAN	PADDY	DRYLAND	141523	188198	1.32981
66	SUMATRA SELATAN	PADDY	DRYLAND	165273	293276	1.77462
67	SUMATRA SELATAN	PADDY	DRYLAND	110494	191125	1.73000
68	SUMATRA SELATAN	PADDY	DRYLAND	123762	224247	1.81192
69	SUMATRA SELATAN	PADDY	DRYLAND	112966	157249	1.39200
70	SUMATRA SELATAN	PADDY	DRYLAND	121538	172705	1.42100
71	SUMATRA SELATAN	PADDY	DRYLAND	127385	168021	1.31900
72	SUMATRA SELATAN	PADDY	DRYLAND	114865	163797	1.42600

TABLE 5.17 Area (Hectares), Production (Metric Tons) and Yield (MT/HA) Statistics for Dryland Paddy Rice in Selected Provinces of Indonesia (continued).

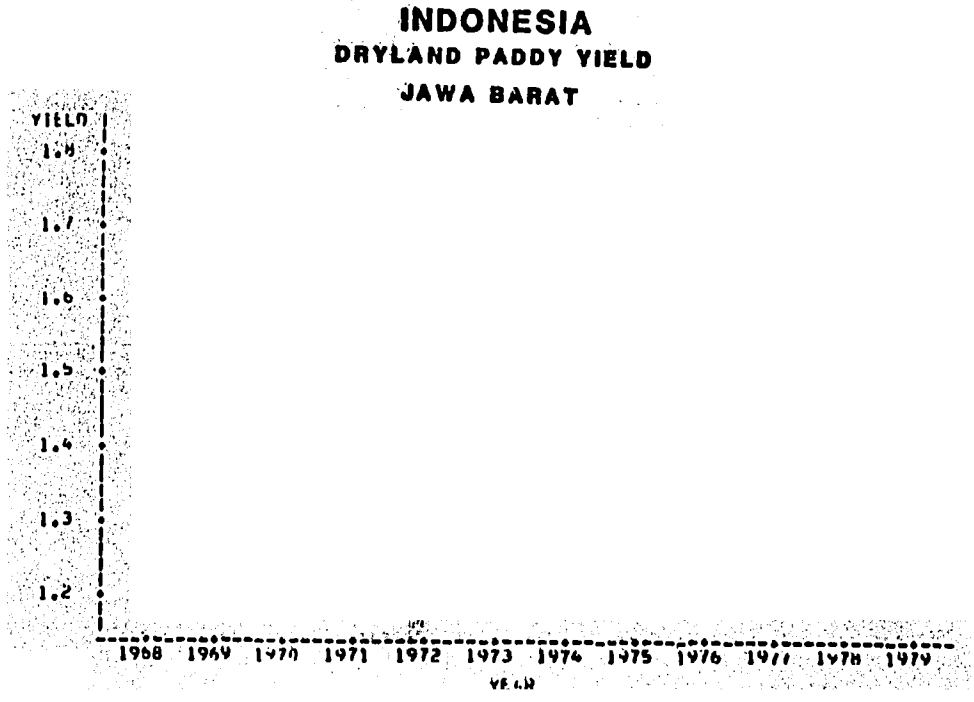


FIGURE 5.10a Dryland Paddy Yield Plots for Jawa Barat Province in Indonesia.

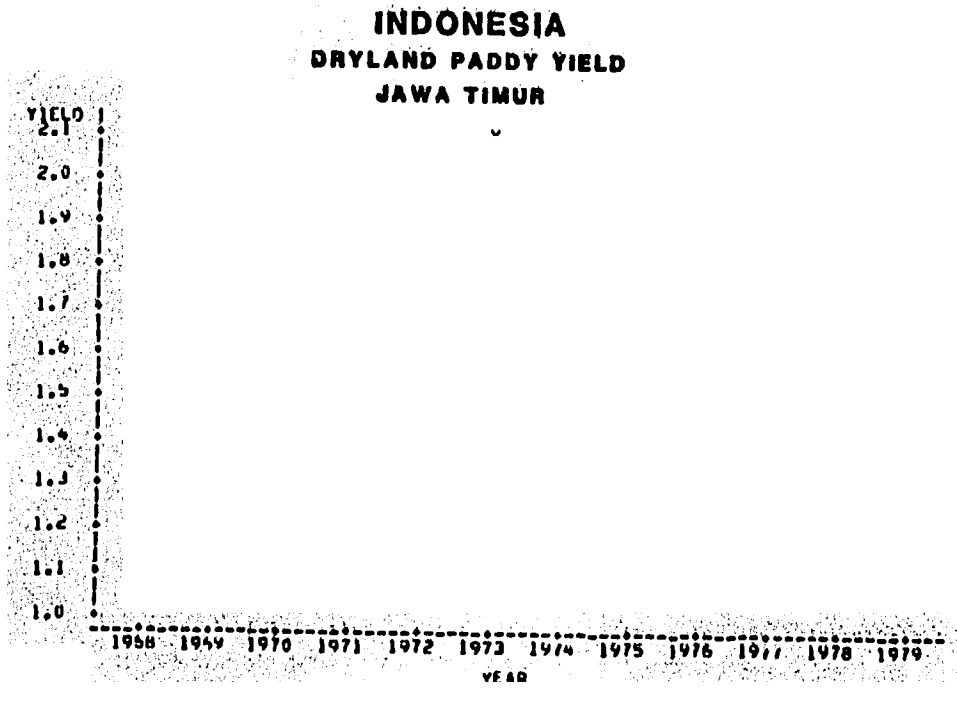


FIGURE 5.10b Dryland Paddy Yield Plots for Jawa Timur Province in Indonesia.

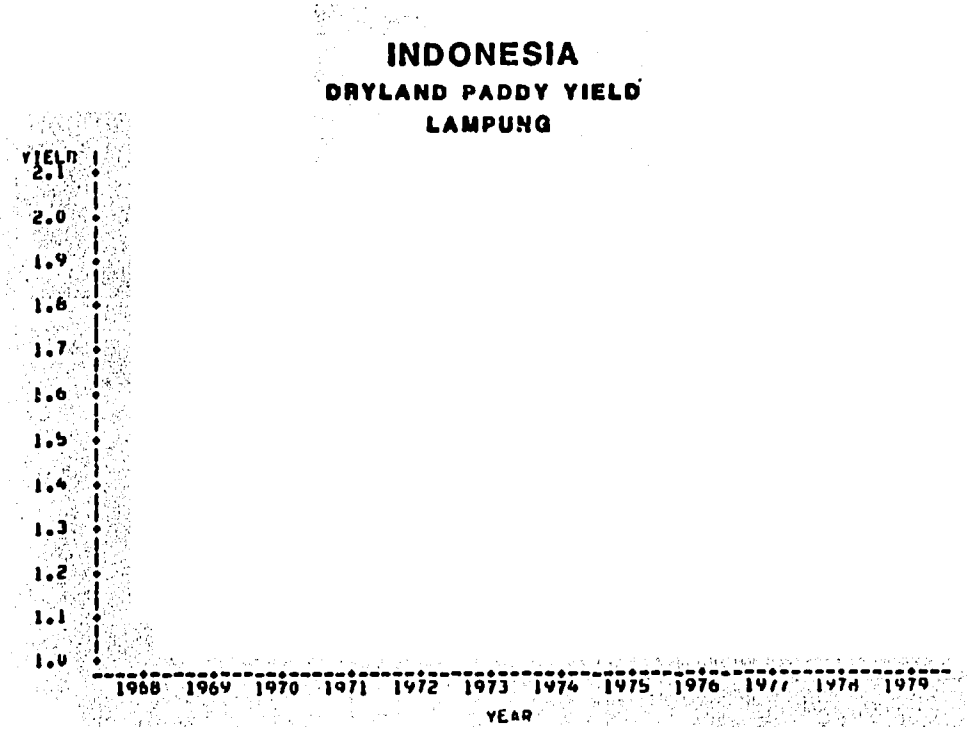


FIGURE 5.10c Dryland Paddy Yield Plots for Lampung Province in Indonesia.

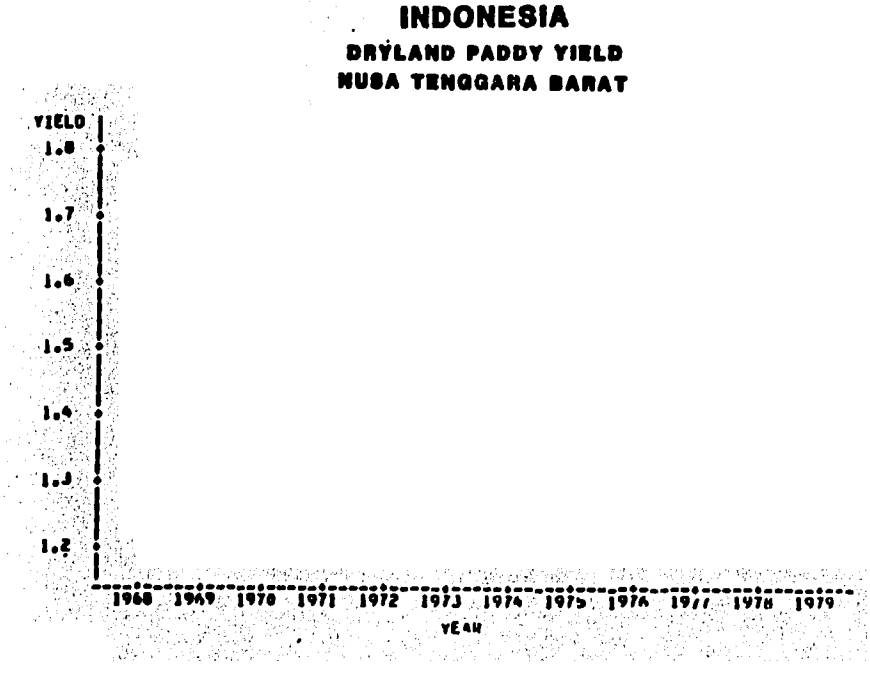


FIGURE 5.10d Dryland Paddy Yield Plots for Nusa Tenggara Barat Province in Indonesia.

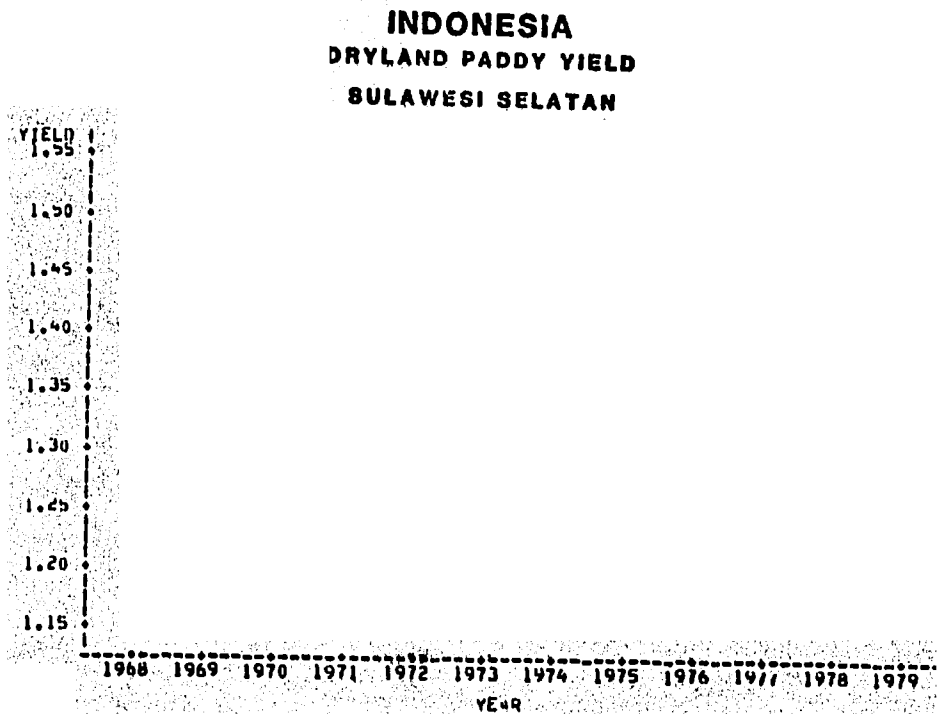


FIGURE 5.10e Dryland Paddy Yield Plots for Sulawesi Selatan Province in Indonesia.

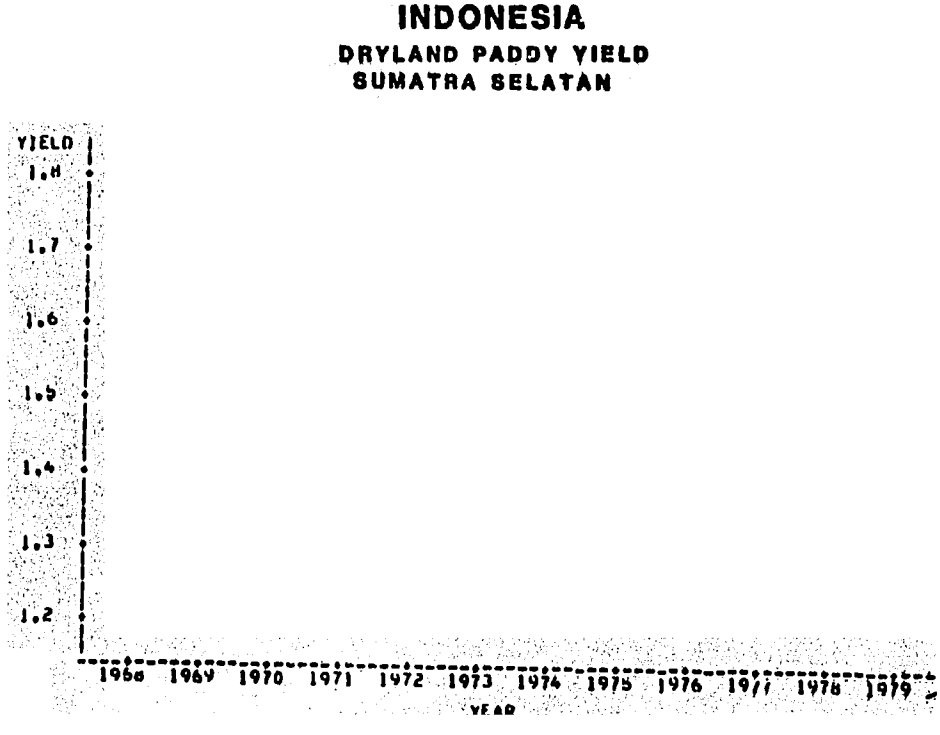


FIGURE 5.10f Dryland Paddy Yield Plots for Sumatra Selatan Province in Indonesia.

and harvesting in February-March. Yield weather correlations for dryland paddy in the study area are shown in Table 5.18a-f. It is desirable to include statistically significant and physiologically meaningful variables in the crop models. An examination of Tables 5.18a-f excludes the possibility of developing meaningful models for dryland paddy in the study area. The negative trend in yield after 1975 may be a major factor in the poor correlations.

CORRELATION COEFFICIENTS / PROB > IRI UNDER HO:RHO=0
/ NUMBER OF OBSERVATIONS

YIELD

P6	LP12	P11	LP2	P3	LP4_7	LP4_7	P7
-0.54061	-0.53939	-0.52139	0.39994	-0.39192	-0.31405	-0.31405	-0.31386
0.0696	0.0868	0.0821	0.2229	0.2332	0.3470	0.3470	0.3205
12	11	12	11	11	11	11	12
LP11_3	LP9	LP5	LP8_9	LP8_11	LP7	YMI	LP6
-0.30057	0.28420	-0.27872	0.27601	0.26577	-0.25741	-0.24520	-0.24118
0.3691	0.3970	0.4066	0.4113	0.4295	0.4448	0.4674	0.4750
11	11	11	11	11	11	11	11
LP8_10	LP11_2	P1	P3_7	LP11	P3	NWPCP	LP8
0.23189	-0.23151	0.23146	-0.22754	0.22193	-0.22087	-0.21821	0.20491
0.4926	0.4934	0.4692	0.4769	0.5119	0.4903	0.5192	0.5456
11	11	12	12	11	12	11	11
P8	P2_7	P4_7	LP11_1	P1_2	P12	P4	P4_5
-0.20007	-0.19192	-0.19142	-0.19082	0.18198	0.17880	0.17877	0.16186
0.5330	0.5501	0.5512	0.5741	0.5713	0.5782	0.5783	0.6153
12	12	12	11	12	12	12	12
P9	P3_6	LP8_1	LP1	LP8_12	P5	P2_6	LP4
0.15562	-0.15461	0.13114	0.12887	0.12428	0.11807	-0.10987	-0.10336
0.6291	0.6314	0.7007	0.7057	0.7158	0.7148	0.7339	0.7623
12	12	11	11	11	12	12	11
P4_6	P10	P1_4	P2_3	P2	LP8_2	P3_4	LP10
-0.09658	0.09139	0.08468	-0.08405	0.07894	0.07570	-0.06545	0.05976
0.7652	0.7776	0.7936	0.7951	0.8073	0.8249	0.8398	0.8615
12	12	12	12	12	11	12	11
P2_5	P3_5	P1_3	LP8_3	P2_4			
0.04954	0.02401	0.01310	0.00854	0.00098			
0.8785	0.9410	0.9678	0.9801	0.9976			
12	12	12	11	12			

TABLE 5.18a Yield-Weather Correlations for Dryland Paddy in Jawa Barat Province in Indonesia.

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0
/ NUMBER OF OBSERVATIONS

YIELD

P2	LP7	P2_3	LP8_3	LP8_2	LP8	NWPCP	LP8_9
-0.86697	-0.78614	-0.70656	-0.67336	-0.67297	-0.63919	-0.63230	-0.62071
0.0053	0.0207	0.0501	0.0973	0.0976	0.0879	0.1276	0.1005
8	8	8	7	7	8	7	8

LP11_3	LP11_2	LP4_7	LP4_7	YMI	P1_3	LP9	LP3
-0.61631	-0.61591	-0.60499	-0.60499	-0.58721	-0.58631	-0.58402	-0.57681
0.1405	0.1409	0.1120	0.1120	0.1657	0.1262	0.1285	0.1344
7	7	8	8	7	8	8	8

LP8_12	LP8_1	LP2	LP10	LP8_11	P1_2	LP12	LP6
-0.57609	-0.56026	-0.52152	-0.51017	-0.48713	-0.48670	-0.47878	-0.47027
0.1759	0.1908	0.1850	0.2421	0.2575	0.2213	0.2771	0.2396
7	7	8	7	7	8	7	8

LP11_1	LP11	LP8_10	P1_4	P8	LP4	P4_5	P6
-0.45939	-0.45865	-0.45379	-0.44169	0.41898	-0.39916	0.33478	-0.31997
0.2997	0.3006	0.3064	0.2732	0.3015	0.3273	0.4176	0.4398
7	7	7	8	8	8	8	8

P2_7	P2_6	P3	P2_4	P4	P7	P2_5	P3_5
-0.31790	-0.31022	-0.27885	-0.27870	0.25331	-0.24556	-0.21642	0.20037
0.4429	0.4546	0.5036	0.5039	0.5450	0.5577	0.6067	0.6342
8	8	8	8	8	8	8	8

P11	P9	P5	P3_4	P12	P10	LP5	P4_6
0.15298	0.13845	0.12856	0.11386	-0.10114	-0.09530	0.08382	0.06645
0.7176	0.7437	0.7616	0.7884	0.8117	0.8224	0.8436	0.8758
8	8	8	8	8	8	8	8

P1	P3_7	P3_6	P4_7	P1
-0.06487	-0.06145	-0.02748	0.02285	0.00998
0.8787	0.8851	0.9485	0.9572	0.9813
8	8	8	8	8

TABLE 5.18b Yield-Weather Correlations for Dryland Paddy in Jawa Timur Province in Indonesia.

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0
/ NUMBER OF OBSERVATIONS

YIELD

LP1	P4	P4_5	P3_5	LP4_7	LP4_7	P3_4	P3_6
-0.69700	-0.69367	-0.68046	-0.66332	-0.60960	-0.60960	-0.57932	-0.57008
0.0251	0.0179	0.0212	0.0261	0.0613	0.0613	0.0618	0.0671
10	11	11	11	10	10	11	11
LP12	P4_6	LP4	P2_5	P9	P3_7	LP5	P2_6
-0.54916	-0.54541	-0.53662	-0.52354	0.49055	-0.48681	-0.48159	-0.47724
0.1001	0.0827	0.1098	0.0984	0.1255	0.1289	0.1587	0.1377
10	11	10	11	11	11	10	11
P2_4	P2_7	P4_7	LP7	LP10	P12	P5	P1_4
-0.43636	-0.43316	-0.41833	-0.37606	-0.35791	-0.34894	-0.34820	-0.33287
0.1797	0.1832	0.2004	0.2842	0.3099	0.2929	0.2940	0.3172
11	11	11	10	10	11	11	11
P3	NWPCP	LP11	LP3	LP8_10	LP8_3	LP8_12	P10
-0.30828	-0.29146	0.24118	-0.23554	-0.22590	-0.20530	-0.18660	0.16883
0.3564	0.4467	0.5020	0.5124	0.5284	0.5962	0.6057	0.6197
11	9	10	10	10	9	10	11
P2_3	LP6	LP8_1	LP11_3	P8	LP8_2	P2	P1_3
-0.16416	-0.16198	-0.14338	-0.13771	-0.13060	-0.13032	0.09956	-0.09614
0.6296	0.6548	0.7129	0.7239	0.7191	0.7382	0.7709	0.7786
11	10	9	9	10	9	11	11
P11	P8	P1_2	LP2	LP5_9	LP11_1	P1	LP9
-0.09226	0.08354	0.08104	0.06844	-0.05536	-0.04701	0.04395	0.03913
0.7873	0.8071	0.8128	0.8510	0.8793	0.9044	0.8979	0.9145
11	11	11	10	10	9	11	10
LP8_11	YMI	LP11_2	P7	P6			
-0.03520	-0.03504	-0.03083	-0.02363	0.00316			
0.9231	0.9287	0.9372	0.9450	0.9926			
10	9	9	11	11			

TABLE 5.18c Yield-Weather Correlations for Dryland Paddy in Lampung Province in Indonesia.

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0
/ NUMBER OF OBSERVATIONS

YIELD

LP5_1	LP11	P4	LP6	P8	P4_7	P4_6	P4_5
-0.72537	-0.72354	0.68685	0.65276	0.64567	0.62132	0.58286	0.53692
0.0650	0.0661	0.0599	0.0793	0.0831	0.1001	0.1294	0.1700
7	7	8	8	8	8	8	8
LP11_1	P2_7	LP8	LP8_9	P1_4	P2_6	LP9	P3_7
-0.46717	0.46133	0.45136	0.41617	0.41577	0.41246	0.39099	0.39069
0.2905	0.2499	0.2616	0.3051	0.3056	0.3099	0.3382	0.3386
7	8	8	8	8	8	8	8
P7	P2_4	P2_5	LP3	P5	LP8_2	P3_6	P3
0.39061	0.39030	0.37948	-0.35198	0.34006	-0.33889	0.32406	-0.31479
0.3387	0.3391	0.3538	0.3925	0.4098	0.4571	0.4336	0.4476
8	8	8	8	8	7	8	8
P12	P2	LP8_11	P1_2	P3_5	P6	LP8_12	LP7
0.31458	0.31075	-0.30248	0.29446	0.29171	0.28816	-0.28673	0.28528
0.4479	0.4538	0.5097	0.4790	0.4833	0.4889	0.5330	0.4934
8	8	7	8	8	8	7	8
LP8_3	LP4_7	LP4_7	LP11_2	P5	P3_4	YMI	LP11_3
-0.28262	0.27308	0.27308	-0.26626	0.25921	0.25104	-0.24152	-0.20439
0.5391	0.5129	0.5129	0.5638	0.5353	0.5487	0.6018	0.5602
7	8	8	7	8	8	7	7
P1	LP4	LP12	P1_3	NWPCP	LP2	P9	LP8_10
0.20413	-0.19950	0.17446	0.16548	0.16520	0.12686	-0.05528	-0.05024
0.6277	0.6357	0.7083	0.6953	0.7234	0.7647	0.8966	0.9148
8	8	7	8	7	8	8	7
LP10	P2_3	P10	P11	P1			
0.04346	0.02354	-0.02191	-0.01672	-0.01304			
0.9263	0.9559	0.9589	0.9687	0.9756			
7	8	8	8	8			

TABLE 5.18d Yield-Weather Correlations for Dryland Paddy in Nusa Tenggara Province in Indonesia.

CORRELATION COEFFICIENTS / PROB > IRI UNDER HO:RHO=0
/ NUMBER OF OBSERVATIONS

YIELD

P8	LP3	P11	LP4	P9	P7	LP6	P12
0.76550	-0.68119	0.65699	-0.63262	-0.59342	0.53890	-0.53712	0.52395
0.0268	0.0920	0.0767	0.1273	0.1601	0.1681	0.2138	0.1826
8	7	8	7	7	8	7	8

P6	LP4_7	LP4_7	LP5	P9	LP1	P4_7	LP8_9
0.52134	-0.49536	-0.49536	-0.44963	0.38369	-0.36371	0.33522	-0.31037
0.1852	0.2583	0.2583	0.2637	0.3481	0.3758	0.4170	0.4981
8	7	7	8	8	8	8	7

LP11	LP8_3	P3_7	P10	LP11_2	LP8_2	LP8_1	YMI
-0.28307	-0.26861	0.26099	0.24297	-0.23496	-0.23323	-0.22184	-0.21692
0.4969	0.5603	0.5324	0.5620	0.5754	0.6147	0.6326	0.6058
8	7	8	8	8	8	7	8

P2_7	LP12	LP11_3	LP2	P4_6	LP11_1	P2	P5
0.21567	-0.21471	-0.21448	-0.20733	0.20243	-0.19655	-0.17216	-0.15682
0.6080	0.6096	0.6100	0.6555	0.6307	0.6408	0.6835	0.7108
8	8	8	7	8	8	8	8

P3_6	P4	NWPCP	LP8_11	LP8_12	P2_6	LP10	LP9
0.14816	0.14512	-0.13624	-0.13335	-0.13250	0.10448	0.09110	-0.08754
0.7262	0.7317	0.7477	0.7756	0.7770	0.8055	0.8301	0.8520
8	8	8	7	7	8	8	7

P3_4	LP8_10	P2_3	P2_5	P1	P1_4	LP7	P1_2
0.07930	-0.07224	-0.06299	-0.04302	0.04178	0.04137	-0.04092	-0.03065
0.8519	0.8777	0.8822	0.9194	0.9218	0.9225	0.9306	0.9426
8	7	8	8	8	8	7	8

P4_5	P2_4	P3	P1_3	P3_5
-0.02176	0.01712	0.01618	-0.01539	-0.00789
0.9592	0.9679	0.9697	0.9712	0.9852
8	8	8	8	8

TABLE 5.18e Yield-Weather Correlations for Dryland Paddy in Sulawesi Selatan Province in Indonesia.

CORRELATION COEFFICIENTS / PROB > IRI UNDER HO:RHO=0
/ NUMBER OF OBSERVATIONS

YIELD

LP1	P9	LP6	LP3	P4	LP12	P4	LP9
-0.75178	0.69043	-0.67514	-0.63417	0.55235	0.54814	0.39489	0.34255
0.0513	0.0580	0.0961	0.1261	0.1985	0.2027	0.3330	0.4520
7	8	7	7	7	7	8	7

P2_4	P2_5	P4_5	LP8	NWPCP	P11	P3_4	LP7
0.34002	0.33164	0.32603	-0.32270	0.31747	0.31441	0.27981	-0.25930
0.4099	0.4223	0.4306	0.4802	0.4878	0.4482	0.5021	0.5592
8	8	8	7	7	8	8	7

LP2	LP5	P3_5	P6	LP4_7	LP4_7	P1	P2_6
0.26439	-0.25327	0.24435	-0.24153	-0.23590	-0.23690	-0.21315	0.21047
0.5667	0.5837	0.5598	0.5644	0.6090	0.6090	0.6123	0.6169
7	7	8	8	7	7	8	8

LP10	P2_7	LP11_1	P5	P4_6	P4_7	P2_3	P12
-0.19247	0.18752	0.16381	0.15007	0.14710	0.14254	0.14174	-0.12901
0.6793	0.6566	0.7256	0.7228	0.7281	0.7363	0.7378	0.7608
7	8	7	8	8	8	8	8

P3_7	LP11	LP11_3	P3_6	P2	P1_4	P1_2	LP11_2
0.12425	0.12418	0.12140	0.12116	0.11734	0.10722	-0.10166	0.07612
0.7694	0.7908	0.7954	0.7750	0.7920	0.8005	0.8107	0.8712
8	7	7	8	8	8	8	7

LP8_10	P7	LP8_12	YMI	P1_3	P3	LP8_11	LP8_2
-0.07100	0.05920	0.05721	0.05470	-0.05355	0.03360	-0.03057	-0.02777
0.8798	0.8893	0.9030	0.9073	0.8996	0.9370	0.9481	0.9529
7	8	7	7	8	8	7	7

P10	LP8_1	P8	LP8_3	LP5_9
0.02523	0.01423	0.01392	0.00803	-0.00051
0.9527	0.9759	0.9739	0.9864	0.9991
8	7	8	7	7

TABLE 5.18f Yield-Weather Correlations for Dryland Paddy in Sumatra Selatan Province in Indonesia.

CHAPTER VI

ASSESSMENT PROCEDURES

This chapter describes the structure of climatic impact assessments, the types of assessments proposed for Indonesia, the agroclimatic models, display of the data, steps in making an assessment and comments on user interpretation of assessments. Test and evaluation procedures for the period May-October 1983 are also discussed.

A. Definition and Assessment Format

1. Definition

The climatic impact assessment is a concise statement which provides decision makers with quantified information on the current or potential effect of climate and weather variability on some aspect of socio-economic activity. Assessments could address agriculture and food security as discussed in this study, other economic sectors (e.g., fisheries, energy, transportation, construction, recreation, health, etc.). The assessment provides decision makers with needed information on climate impact, one of the many factors which influences policy and economic planning. Assessments represent a method for converting meteorological data into economic information. This process can be viewed as a means for interdisciplinary communication and in many cases promote interagency dialogue.

The meteorologist prepares a basic assessment from agroclimatic models and real-time meteorological input data. The assessment is provided to users such as food security managers, economic policy analysts, agricultural statisticians, extension officials and others. They can use the assessment to supplement information from other sources available to them. This process can frequently benefit the user's individual products, reports and forecasts. For example

the agricultural statistician or economist involved in the crop production and yield forecast problem can combine the assessment with analysis from area farm survey results, crop cutting reports, farmers reports and other data sources.

There are no fixed rules for preparing an assessment and it is very important to adapt the assessment to individual user needs. However, the following basic structure is recommended.

2. Format

The format for an assessment includes the following sequential statements: 1) Impact, 2) Perspective, 3) Model Results, 4) Weather Analysis and 5) Support Information. Only information and data relevant to the impact are used in statements 2 through 5. These justify the impact statement.

Impact

This is the statement which directly communicates needed information to the decision maker. The terminology is strictly associated with the user's discipline. Preparing the impact statement is the most difficult task of the assessor. It must be objective and clearly stated.

Some example statements could include: 1) there will be a crop failure in Region X due to drought, 2) crop conditions are very poor in Region X and potentially represent the worst case of crop failure in the last 10 years, 3) there is the potential for isolated food shortages in Region X due to severe drought, or 4) agricultural crops are in very good condition and the prospects for this year's harvest are exceptionally good. If abnormal rainfall was a problem in the early part of the growing season, the impact statement could be, "farmers probably could not plant" or "planting was delayed due to a delayed rainy season (heavy rains)", etc.

The impact statement does not include any technical discussion of meteorological events or data. These are described in subsequent portions of the assessment.

Perspective Statement

The perspective statement can be used to qualify the impact by describing the expected scope and magnitude of the potential problem. For example, the statement that a maize crop failure is likely in Region X could be followed by a statement which describes the favorable situation at other locations within Region X or other regions in the country. Another example is, "this is the worst drought in the past 30 years." The decision maker is provided with information on, "how large is the expected problem."

Model Results

The perspective statement is followed by a discussion which lists the quantitative results from the assessment models. The model could be a drought or crop condition index, a statistical crop yield model or soil moisture information. The model output is presented as a percent of normal or percentile rank. For example, the statement could be "Agroclimatic/crop condition indices are 60 percent of normal which is below the 20th percentile", or "The southwest monsoon index is at the 5th percentile which has a probability of occurrence of about one chance in 20." Decision makers frequently find it useful to know how this year's information compared to last year (e.g., as a percent of last year) or by also listing recent good (poor) years which are comparable. For example, an assessment of crop conditions made at the end of August and describing conditions as bad or worse than conditions in Indonesia during 1979 would be well understood by users.

Weather Analysis

The weather analysis section describes the weather and climatic conditions which were associated with the impact. Only relevant information and data are provided. Information such as seasonal rainfall amount, monthly rainfall, tropical storm conditions, etc., are provided. Statements on the behavior of the monsoon (erratic, late arrival, early retreat, etc.,) are included. This is the classical weather description.

Support Information

The very last portion of the assessment is optional and provides reliable support statements taken from secondary sources of information. For example, reports from the field would be appropriate. News media accounts are generally not recommended.

B. Types of Assessments for Indonesia

This study developed three types of assessments including: 1) Drought Early Warning, 2) Agricultural Crop Condition and 3) Weather Advisories for the Extension Service. Depending on the user's requirements, the drought early warning and crop condition assessments can be combined into one report. The advisory assessment for the extension service should provide weather analysis in great detail and considerable information and data on soil moisture. A table providing soil moisture estimates for each month could be included. The specific requirements and format desired by users must be obtained.

C. Frequency for Making Assessments

The models developed in this study use monthly meteorological data; therefore, primary assessments are made within about 5 days after the end of each month during the growing season. However, update assessments providing current weather and other qualitative information can also be provided each week or every two weeks. These help the user maintain continuity.

Frequently, users require special assessment reports which elaborate on the potential impact problems. These could be 5-10 page reports.

Assessment models could be developed from decadal meteorological data (e.g., 10 day total rainfall) and assessments made every 10 days.

D. Assessment Models

Primary Models

The primary assessment models to be tested include the Generalized Monsoon Index (GMI) for the June-September rainy season, the Yield Moisture Index (YMI) defined for main rainy season maize and rice, monthly soil moisture estimates determined from the Palmer two-layer model and preliminary statistical climate/crop yield models for main rice and maize crops.

The historic indices have been summarized in computerized tables and time-series plots for each station in Indonesia (see Chapter V for examples). The index is listed for each year and assessment period (GMI: Table 5.3 and Figure 5.1; YMI: Tables 5.4-5.7 plus Figures 5.2 and 5.3). Indices are expressed in raw numerical form as well as percent normal and percentile rank. Percentile ranks range from zero to 100. Each table can be used as a worksheet to compute real-time index values for the current year (1982, 1983, etc.). Current year index values can also be placed on the time-series plots for analysis. The tables and graphs permit the assessor to easily make comparisons with previous index years.

Each index has also been summarized in tables which provide index values for each location but for a specific year. This is useful in performing a spatial analysis.

Soil moisture tables provide monthly moisture estimates for each layer in the soil (see Table 5.8).

Secondary models

The climatic diagram and the Palmer Drought Index (PDI) are very important secondary assessment tools. The climatic diagram can be determined from the soil moisture budget tables; however, the PDI (Figure 5.4) is usually calculated on a computer.

The climatic diagram can be presented in either table or graphic format. It is very useful as a tool to analyze conditions during the progress of the crop season.

The extension service and other users may be interested in receiving this information as a regular assessment product. Variables would include monthly rainfall, normal Potential Evapotranspiration (PET), Actual Evapotranspiration (AET), Soil Moisture (SM) and runoff. Rainfall or soil moisture normals could also be added.

It is also possible to define normal PET values for 10 day periods within each month. These can be used with real-time, decadal rainfall to provide the climatic diagram assessment every 10 days. Daily assessments can also be developed. For example, NOAA/AISC converts monthly rainfall normals into daily normals. This same process could be used with PET.

E. Display of Data

In addition to the tables and graphs discussed above for the index models and climatic diagram, there are other useful ways to display the data for enhanced analysis. For example, it is useful to prepare station location maps and to spatially analyze rainfall data and index values. Rainfall data can be plotted as a percent of normal for individual months or the growing season. Cumulative rainfall during the growing season can be displayed on a graph which also shows the normal cumulative rainfall.

F. Steps for Preparing Assessments

Some of the suggested procedural steps for preparation of an assessment include:

1) Obtain monthly rainfall data for the assessment stations and conduct quality control. Perform a spatial analysis.
2) Enter the rainfall data into the tables for the GMI, YMI and Soil Moisture.
3) Calculate the raw values for the GMI and YMI for the assessment period, as appropriate.
4) Calculate soil moisture, AET, etc.
5) Use the historic index tables to calculate percent of normal (YMI & GMI) and interpolate the percentile rank from the tables.
6) Plot the GMI and YMI percentile rank on the historic time-series plots.
7) Determine climatic diagrams for the current year.
8) Prepare maps which indicate the spatial variability of rainfall (percent normal) and indexes (percentile rank).
9) Prepare the assessment using the above results and in the recommended format as outlined above, and
10) Obtain approval for the assessment and distribute to users in the Ministry of Agriculture and others, as appropriate.

G. Comments on Interpretation of Assessments by Users

The assessment should be viewed as an additional source of information that is available for making decisions on drought early warning, crop condition analyses and extension services. The assessment <u>only</u> provides information in potential or actual climatic impact. It does not consider the many other factors, for example, which could cause crop yield variability. These may include changes in planted area, fertilizer and pesticide applications, varieties and

other management decisions; crop losses due to pests are not assessed. The assessment is most reliable for potential drought impact, not flooding damage or other extreme weather events.

Drought impact can be reliably assessed by about 30 days before the crop harvest. This may represent as much as 3-6 months lead-time before economic impacts.

H. Comments on Test and Evaluation

It is proposed that the assessment models be tested and evaluated during the 1983/84 growing season. Test assessments would be prepared at the end of May, June, July, August, September and October. These would be provided to users.

The purpose of this test period is to evaluate the models, learn how to interpret them, gain experience in preparing the assessment and to establish a dialogue with users. The users needs must be determined and their comments are very necessary.

CHAPTER VII

SUMMARY AND RECOMMENDATIONS

This program focused on rainfed agriculture in Indonesia because of its drought vulnerability. The climatic impact assessment models developed during this program should be tested and evaluated before operational assessments are provided to users. Test assessments based on real-time meteorological data can be provided to interested users in government. Assessments can be evaluated and verified according to user comments and reliable field reports. The usefulness of the agroclimatic indices and models can be determined. It is also desirable that similar models be developed for other regions. This can lead to a national climatic impact assessment program.

The major goal of this assessment program is to help decision makers and economists mitigate potential climatic impact on crops and the national economy by providing reliable, timely, yet inexpensive information on potential climatic impact. The assessments obtained from the models can be made 30 days in advance before harvesting of crops. This can represent a 3-6 month lead-time before national and regional economic impacts occur. This should certainly help users either in the governmental agencies or the public make economic decisions ranging from drought mitigation to land use planning.

One advantage of these agroclimatic indices and models is that they are simple. The assessments and models are purposely designed for manual operation. However, it is desirable to have computer facilities for faster and more accurate processing. In addition, more information concerning the phenological stages of the main crops at the provincial level should be obtained and analyzed together with the available climatological information. Finally, knowledge of

local practices constitute an important requirement for the modeling as well as for the testing of the model.

The Meteorological Department has agreed to be the NOAA/UMC focal point in Indonesia for this technology transfer program and also to provide climatic impact assessments to appropriate agricultural and economic agencies. Thus, a staff or working group in this program should be set up. Cooperation with all other government agencies that deal with agriculture, land use and economics will help make the program worthwhile. Meetings between the staff and other governmental officers should be held to determine what other agencies need or whether they prefer to have the assessments made for some particular cases, areas or periods. Exchange of knowledge and real-time data on meteorological elements or agricultural information, soil condition, phenological data, yield, etc., should be encouraged. Local knowledge is also important. It can be provided either from other government agencies or through field surveys. The models and assessments will be of higher efficiency and more accurate if both the meteorological and agricultural experiment stations are linked together, i.e., the agricultural stations should have weather instruments installed within the area so meteorological elements there can be observed. As a result, the models obtained will be well represented in that region and greater efficiency in assessments can be provided.

The models developed will be tested and evaluated in 1983. Thus, the first trial assessments will be made and their usefulness can be estimated. Some adjustments will probably be made to improve the models in various areas.

It is hoped that this technology transfer to Indonesia will help the government mitigate potential drought impact on the region as well as the country. Early warning and preparedness for severe weather impacts on both agriculture and the economy can be made.

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