PN-ABH-763

71217

EARLY WARNING ASSESSMENTS OF DROUGHT USED BY THE U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

BY

N.D. Strommen [1/]

P.F. Krumpe [2/]

M. Reid [3/]

L.T. Steyaert [4/]

August, 1980

RECEIVED
AUG 13 11 19 AM '80
FFP/POD

1/ Chief Meteorologist, World Food and Agricultural Outlook and Situation Board, USDA. (Formerly Chief Climatic Impact Assessment Division, EDIS/CEAS.)

2/ Science Advisor, Office of U.S. Foreign Disaster Assistance Agency for International Development, AID/OFDA.

3/ Chief, Climatic Assessment Branch, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, Center for Environmental Assessment Services, NOAA/EDIS/CEAS.

4/ Research Meteorologist, Models Branch, National Oceanic and Atmoshperic Administration, Environmental Data and Information Service, Center for Environmental Assessment Services, NOAA/EDIS/CEAS.

EARLY WARNING ASSESSMENTS OF DROUGHT USED BY THE U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

by

Norton D. Strommen, Paul F. Krumpe, Malcolm Reid and Louis T. Steyaert

001193

INTRODUCTION

The Agency for International Development's Office of U.S. Foreign Disaster Assistance (AID/OFDA), has the mission of responding to international disasters and implementing U.S. actions to meet the needs for emergency assistance requested by the disaster stricken countries around the globe. These requests often can be related to climate anomalies. For example, many developing countries are located within the semi-arid climatic belts where rainfall is highly variable and food production is directly dependent on availability of adequate rainfall. During a period of favorable climate in the early 1960's, a rapid growth in population was experienced in these semi-arid regions. During the same period, less than optimum management practices often were used in these regional agricultural programs resulting in reduced potential future food production, even with ideal climate. Poor land management practices and resulting soil erosion have been demonstrated to further increase the variability of indigenous food supplies, given the same climatic patterns. This condition is referred to as "pseudo drought," such as has occurred in Haiti and analyzed by Steyaert, et al.(1979a).Thus, when severe drought occurred in the late 1960's and early 1970's the resulting food shortages were socially disruptive and economically disastrous.

To be most effective in accomplishing its mission, AID/OFDA needs an early warning information or alert system to provide the necessary information to determine potential needs before a "creeping disaster" such as drought reaches the critical stage. The purpose of the AID/OFDA program support of National Oceanic and Atmospheric Administration's Center for Environmental Assessment Services, Climatic Impact Assessment Division (CEAS/CIAD), has been to develop such an operational system to provide early warning information on potential food shortages due to drought. This system will allow AID/OFDA to achieve a more cost effective response capability in meeting the following goals:

1) Monitor and assess to the fullest extent possible, all potential and actual disaster situations due to drought.

2) Increase the U.S. technical capacity to define disaster-prone conditions and to recommend disaster-avoidance measures.

3) Apply and transfer both technology and information to developing countries, international organizations and others to insure maximum possible lead-time and warning of these potential disasters.

AID recognizes that the primary responsibility for worldwide assessment and warning of drought-induced crop shortfalls is vested in United Nations cooperating agencies such as the World Meteorological Organization (WMO), and the Food and Agriculture Organization (FAO), as well as the U.S. Department of Agriculture's World Food and Agricultural Outlook and Situation Board. Further, the governments which receive the data hold total responsibility for interpreting assessments, decision-making, and issuing warnings to their population. AID/OFDA therefore focuses its agro-climatic early warning activities on:

1) Encouraging U.N. agencies to incorporate into their assessment and warning system the applicable techniques and results developed by Environemntal Data and Information Service/Center for Environmental Assessment Service (NOAA/EDIS/CEAS).

2) Transferring agrometeorological technqiues to host governnment agencies which require technical assistance.

3) Advising users on appropriate data interpretation, analysis, and dissemination.

This paper will discuss the current status of project activities supported by AID/OFDA and conducted by NOAA's CEAS to develop an Early Warning Assessment program. The project includes "Study of the Caribbean Basin Drought Food Production Problem" (CEAS 1979a)," "Weather Crop/Yield Relationships in Drought-Prone Countries of Sub-Saharan Africa", (CEAS 1979b), and "Climatic Analysis and Development of Weather/Crop Yield Forecast Models for Southeast Asia and the Indian Subcontinent." 1/ Program objectives concentrate on the development and institutionalization of climatic/crop yield models designed to monitor and forecast relative crop yields for subsistence agriculture. These models are generaly based on comprehensive meteorological and agricultural data bases, detailed crop calendars, information on crop regions and cropping practices which are often determined in cooperation with host government scientists and establilshed agrometeorological principles. This agroclimatic program is currently developing an operational system for the rapid dissemination early warning information on drought impact to host governments, international organizations and other users. The provision for technical assistance in the interpretation, application and integration of assessment data into drought/famine disaster decision processes, planning and preparedness is an integral part of this effort.

CEAS EARLY WARNING ASSESSMENT PROGRAM

Qualitative, operational assessments are currently issued on a weekly basis for 26 climatic regions in the Caribbean basin and 110 in Africa. These assessments will soon be expanded to include 107 agroclimatic regions in

---

1/ (Related papers include Motha and Strommen, 1979; Motha and Sakamoto, 1979; Steyaert et al. (1979 b.).

Southeast Asia and the Indian Subcontinent. Crop yield models including agro-climatic indices for the Caribbean Basin and Sub-Saharan Africa are currently undergoing a period of test and evaluation. These models are used to make monthly crop assessments which are included as part of the weekly assessment reports; supplemental assessments are issued if warranted by adverse crop conditions.

WEEKLY WEATHER ASSESSMENT REPORTS

Information Sources, Techniques and Summarization, Assessment Information, and Reports and Publications represent the four basic components of these weekly assessment reports as follows:

1. Information Sources

Information sources for the Early Warning Assessment Program include surface weather observations, climatological normals, historical data, surface and upper air analyses, satellite imagery, and such ancillary information as abstracts from the N.Y. Times Information Data Base, USDA foreign attache reports, and reports from the Foreign Broadcast Information Service.

a. The National Weather Service's National Meteorological Center (NMC), uses telecommunications processors to secure near real-time international weather data from the WMO's high-speed Global Telecommunications System synoptic weather observation reports on winds, temperatures, precipitation, visibility, weather phenomenon, atmospheric pressure and clouds are received at either 3 to 6 hour intervals from over 8,000 weather stations worldwide.

Meteorological "normals" for about 4,000 stations worldwide and for stations aggregated into agroclimatic regions are stored on the NOAA computer.

Similarly, historical series of meteorological data are used to determine the probability of occurrence of various climatic hazards.

b. Unfortunately, distribution of the ground reporting weather stations World-wide is not uniform. Sparse to nonexistent coverage prevails over most of the areas of primary interest to AID; i.e., the Caribbean Basin, Africa, the Middle East, and southern Asia. Therefore, other information sources are required to supplement the limited number of ground station reports in these regions and to provide quantitative estimates of those weather events of particular interest to AID. Drought is frequently the cause of prolonged, widespread destruction and misery in developing countries. However, precise area estimates of total rainfall are probably the most difficult of all meteorological evaluations due to the non-conservative nature, skewed frequency distribution and high variablity of this parameter. Therefore, a major CEAS function in support of AID is to estimate rainfall amounts within each agroclimatic region in order to identify and delineate areas of potential or ongoing drought.

Frontal systems, troughs, convergence zones and other dynamic weather disturbances are portrayed on the surface and upper air analyses that are charted four times daily by the NWS. These charts are used to identify regions in which atmospheric dynamics suggest the occurrence of precipitation. Outlines of rather broadscale precipitation types and intensities are produced.

Satellite imagery from the NOAA 6, TIROS, GOES, and DMSP weather satellites is used to quantify estimates of total rainfall. A rainfall estimation procedure discussed by Follansbee (1973) has been adapted for use in the AID/OFDA program. A limited test of this procedure using weekly and four week total rainfall reports from an average of over 50 stations in Puerto Rico was conducted from January 7 to December 8, 1978. The results suggest that:

1) Rainfall estimation techniques exclusively based on satellite imagery interpretation are marginally reliable in the tropics. Use of this technique does not eliminate the need for a sound network of ground station reports. However, it does provide a useful tool in the absence of other information. When used in conjunction with other information sources, it offers a far better precipitation estimation tool than would otherwise be the case.

2) The reliability of rainfall estimates based entirely on satellite imagery increases as the time span increases. Daily and weekly rainfall estimates are effective in qualitatively identifying wet or dry areas, while monthly and seasonal rainfall amount estimates are far more quantitatively reliable.

3) Present satellite-based techniques tend to underestimate rainfall amounts during periods of heavy rainfall; thereby making this technique more effective in locating droughts than floods.

4) Satellite imagery is highly effective in determining persistent cloud free areas, i.e. no rain.

c. Other ancillary information derived from atlases, local publications, area handbooks and World Bank reports are used to identify major in-country societal activities. Such sources provide insight into the likely sensitivity of an individual society to meteorological events. Interelated activities such as transportation, hydroelectric power generation, energy consumption, subsistence agriculture, and economic and social stability may suffer different impacts due to differing combinations of meteorological parameters. However, the factors having the most severe impact are usually drought, extreme rainfall, anomalies and severe tropical storms.

2. Techniques and Summarizations

The Information Sources collectively support the following CEAS tools which provide the processed assessment information contained in the CEAS Early Warning Assessments.

a. Meteorological data printouts and map-plots based on CEAS computer programs summarize the precipitation and temperature information contained in surface observation reports stored in the NMC data base. A 7-day summary for the period 0000 GMT Monday through 2359 the following Sunday, describes the major weather events at 3-hour intervals throughout the 7-day period, the 24-hour and 7-day precipitation totals, daily maximum and minimum temperatures, and weekly maximum, mean, and minimum temperatures. (Internal program checks provide some quality control.) This summarized information is prepared for

each of the 8,000-plus stations in the NMC data base and for selected groups of stations that form agroclimate regions. A similar summary provides total monthly precipitation, percentage of normal rainfall, plus maximum, mean and minimum temperatures and their percentage departures from normal for the month. Much of this 7-day and monthly precipitation and temperature information is machine-plotted on charts that cover the globe north of 40°S.

b. The Episodal Event Printout which is based on a CEAS computer program searches the world weather observational data contained in the NMC data base and provides a daily printout of anomalous weather events. High winds, very heavy precipitation and temperature extremes are examples of this category which are known to have specific impacts in developing countries.

c. Two examples of major special technique programs developed by CEAS to detect drought and flood areas are concerned with cumulative precipitation and percent of observations reporting precipitation. The cumulative precipitation program compares reports of weekly precipitation with respective normals and identifies "drought" as the occurrence of less than 60 percent of normal precipitation for a minimum of eight consecutive weeks. Stations or agroclimatic regions that fall below the 60 percent threshold for at least 8 weeks are continued in this "drought" category until sufficient rainfall occurs to raise the cumulative precipitation for the most recent 8-week period to at least 60 percent. A second component of this program is based on climatological normals and indicates the number of weeks of normal precipitation that would be required to alleviate the drought, i.e., to raise the 8-week precipitation totals to at least 60 percent of normal. The percent of observations reporting precipitation program provides the weekly percentage of all weather observations within each agroclimatic region that report a weather event (snow, rain, hail, showers, etc.) which indicate that precipitation is occurring. This percentage is used in two ways: first, it is empirically related to historical quantitative precipitation amounts to provide an estimated precipitation, and second, it is compared with historical percentages to determine if reports of rainfall have been less than, near, or more than the usual percentages of normal.

3. Assessment Information

The Techniques and Summarizations function, which utilize daily and weekly data from the information sources, provide the basis for preparation of early warning assessments. These assessments have four components as follows:

a. Integrated rainfall amounts are the 24 hour estimates which are derived for all regions of interest to AID. These estimates are supported by the meteorological information sources (surface weather observations, surface and upper air analysis and satellite imagery) as discussed in the Summaries and Techniques section. The reliance placed on the individual summary or technique varies with data availability and with the region of concern. These precipitation estimates are also used as input for the crop models discussed in the following sections.

b. Yield estimates made by climate/crop yield models provide definitive information on drought impact to agriculture.

c. The unusual weather-related events that can have a striking socio-economic impact (such as drought, flood and other violent weather) are derived directly from the integrated rainfall amount estimate, episodal events, programs, cumulative precipitation, and the percent of observations with precipitation programs.

d. The probability of occurrence of key meteorological events utilizes statistical analysis of historical series of meteorological data to provide required probabilities. Past and present weather information is required to determine the current level of anomalous climatic events pertinent to AID, after which probabilities are derived for the alleviation, continuation or intensification of these events.

4. Reports and Publications

The culmination of this comprehensive effort is the preparation of the weekly CEAS Weekly Weather Assessment Reports. Currently, regional assessements are published for the Caribbean Basin and African continent including the adjacent islands. Reports of the 107 agroclimatic regions in southern Asia (from Pakistan and India to Indonesia) will be published in the near future. These early warning assessments represent the major input to AID. Other related publications include: 1) "Environmental/Resource Assessment and Information Report," dealing with some of the major agricultural areas of the world; 2) "Major World Abnormal Weather" (a brief report designed primarily for congressional use), and 3) "Impact Assessment of Major Climatic and Other Natural Events," (primarily for those concerned with large scale economic issues).

CROP MODEL DEVELOPMENT

Climate crop yield models are based on physical relationships between environmental data and crop response include plant-water requirements for each major growth stage. The crop modeling system is designed to accommodate constraints which may include the limited availability of 1) both historical and real-time meteorological data, 2) reliable crop yield data, and 3) crop calendar information. Additionally, the system is broad enough to consider the type of crops which are produced, and yet sufficiently low-cost for practical operation.

In addition to these constraints, there are important considerations associated with subsistence agriculture, particularly in semi-arid zones. For example, subsistence agriculture is based on "built-in" safeguards which tend to ensure at least minimal returns except in the very worst of drought years. Agricultural practices such as multiple plantings over a 30-60 day period, the variety of crops grown, intercropping, and other distinctive cultural practices (e.g., decisions on crop planting dates) must be considered in the development of the models. In spite of these constraints and considerations, some important assumptions can be made to develop crop yield models including agroclimatic indices. Some of these include:

1) Year-to-year variability in yield is largely due to variations in rainfall for a given region. In many cases soil fertility and crop variety act together as overall limiting factors.

2) Analysis of cumulative precipitation has been demonstrated on an operational basis to be a practical indicator of climatic impact on crops.

3) In the case of subsistence level farming, the level of technology is very low and relatively constant from year-to-year.

4) Information on crop calendars and agricultural practices is generally available or can be inferred from agroclimatic analysis.

5) Scientific studies are available to provide significant information on plant-water requirements by growth stage, climatic/crop relationships, and discussion of various types of crop modeling approaches.

6) Verification and validation of crop indices developed for data-limited regions can be partially accomplished by analysis of episodal data bases which include the various reasons for abnormal food shortages and/or famine.

Information on these factors permits the development of the appropriate hypothesis on which to base the model, i.e., the time and space scale considerations for aggregating the data, selection of potential predictors, and the type of analysis.

1. General

Three approaches were used to develop crop models depending on the availability and reliability of yield data. These approaches included the traditional regression type climate/crop yield model based on monthly data for regions with at least marginally reliable crop yield data, analogue crop yield models, and agroclimatic indices. In the second approach, traditional climate/crop yield models were used as analogues to regions to provide relative yield estimates. Analogue regions were defined as having climatic conditions and cropping practices very similar to the country which had available climatic data but limited crop data.

Both analogue yield models and agroclimatic indices were used to generate historical, relative yield indices from cilmatic data (i.e., 1920-1978 for the Caribbean Basin and 1950-1977 for Sub-Saharan Africa). Yield assessments are based on a comparison of the real-time estimates to historical indices which in some cases have been scaled according to the severity of known occurrences of abnormal food shortages and famine. In this respect historical climatic data, which are expressed as a crop index, are linked with socio-economic data to determine the degree of food shortage, as well as antecedent conditions (both weather and non-weather factors) which tend to be associated with the food shortage.

Long-term records of monthly precipitation, monthly temperature, and day-length represent the basic input data (Figure 1). Crop data include crop coefficents, the critical growth stage as well as crop calendar information, i.e., the normal time of planting, flowering, and harvest dates. Soil data include specific information on soil type and general characteristics such as the water holding capacity of the soil for the mean depth of the crop rooting zone(plant available water could only be estimated).

As indicated by the arrows in Figure 1, various budgets and indicators are computed. For example, one type of soil moisture budget which was used is based on a modification of Palmer's (1965) method. Various agroclimatic indices which relate to the soil moisture and the heat stress on the crop are included in the analysis. Episodal data such as cases of abnormal food shortages are being used for crop index verification as discussed above.

Several crop response indicators were used as candidate predictors in modeling and analysis because of the range of climatic conditions in countries of interest. Some of these indices include:

1) R-Index (Yao, 1969)

The upper limit of evapotranspiration can be considered as the potential evapotranspiration (PET). The actual evapotranspiration (AET) is the actual water loss from the plant-soil system and is limited by the available water supply. The R-index is a measure of plant water supply in relation to plant water requirements. The R-index is defined as:

$R = AET/PET$ where $0 \leq R \leq 1$.

This index can be used as a tool for analyzing the effect of water stress on crop response as well as estimating optimum crop planting dates to ensure adequate moisture during critical growth stages.

2) Soil Moisture Index (Ravelo and Decker, 1979)

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

For SW $\leq$ Field Capacity, the SMI is defined as:

$SMI = PAW/(PAW_{max})$ where $0 \leq SMI \leq 1$.

3) Crop Moisture Ratio (CEAS, 1979b)

Precipitation (P) is the major moisture input in the soil water balance equation for some climatic regimes, particularly for crops grown in rain-fed regions which experience alternate dry and wet seasons. In some cases it can be demonstrated that the actual evapotranspiration is equivalent to precipitation. The R-index is modified under these conditions and the crop moisture ratio (CMR) is defined as:

$CMR = P/PET$.

4) Yield Moisture Index (CEAS, 1979a)

Water availability is recognized as the major determinant of yield in many tropical regions. If rainfall at the ith growth stage (P_i) is below average, crop yield will be reduced, especially for critical stages and extreme condi-

AGROCLIMATIC ANALYSIS

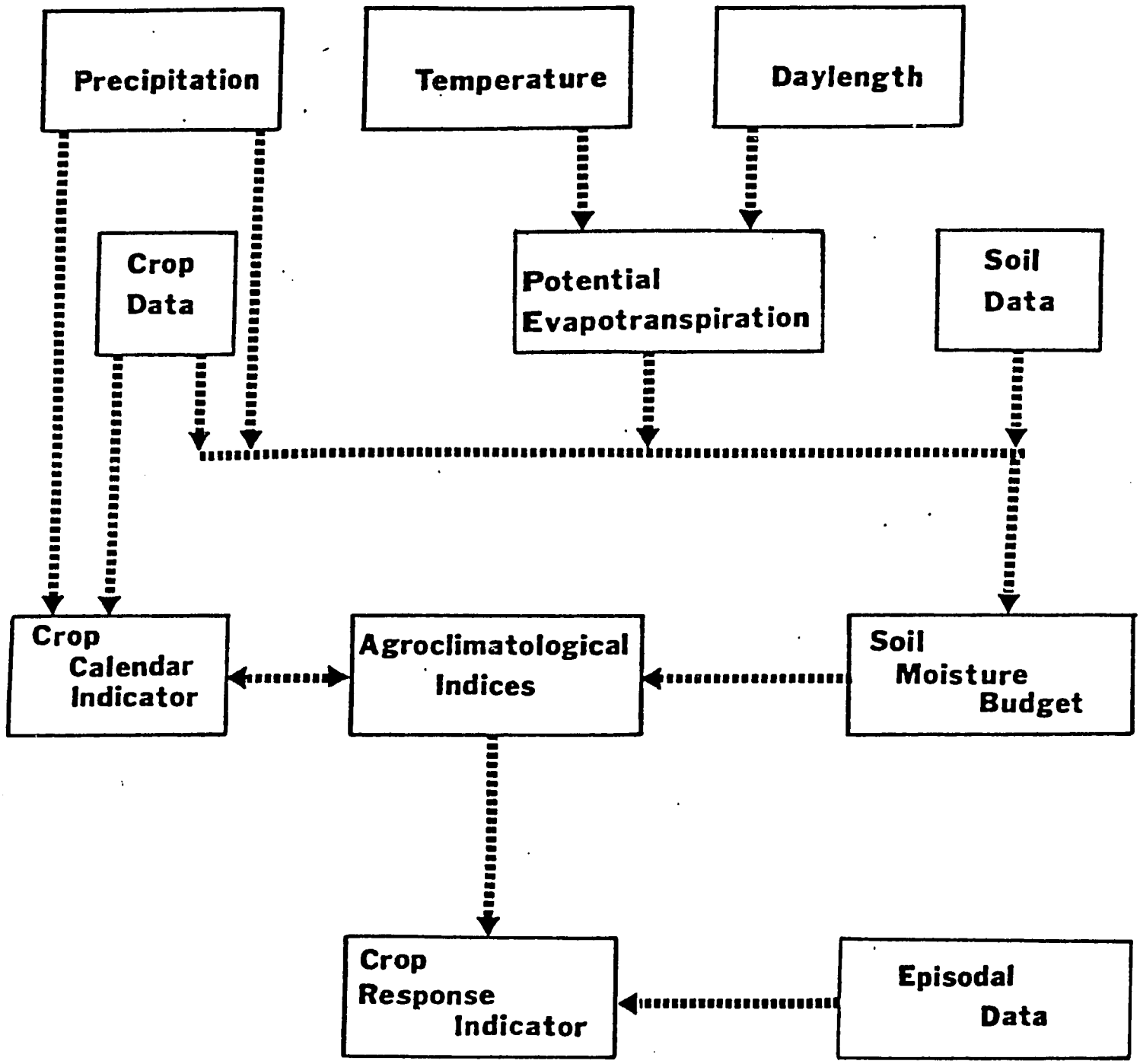

Figure 1. Various inputs and outputs for agroclimatic analysis used in NOAA/CEAS Early Warning analysis (NOAA/CEAS, 1979a).

tions. Doorenbos and Pruitt (1977) provided crop coefficients (KC) for various growth stages of several crops. The crop coefficient was experimentally determined and defined as the ratio to the crop specific potential evaportranspiration to reference potential evapotranspiration. In part, these coefficients provide information on the plant water requirements by growth stage, such as the critical growth stage which is usually the flowering stage. For example, the crop coefficient for corn at planting is 0.35 which compares to a coefficient of 1.05 for corn at silking. Therefore, moisture is approximately three times more important at silking than at planting. If water requirements are not met during silking, the crop will suffer stress which will reduces yield.

The yield moisture index (YMI_j) for crop j is defined as:

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

where $P_i \leq$ Field Capacity, and KC_{ij} is the appropriate crop coefficient for the ith crop growth stage, i = 1, . . . , N and the ith crop.

Because precipitation is weighted according to plant water requirements for each growth stage, the YMI_j represents an improvement on cumulative precipitation. Rainfall data are censored to the field capacity as an approximation to account for the runoff associated with extremely wet months.

2. Traditional Climate/Crop Yield Models

This modeling approach was restricted to countries where crop yield data were considered to be reliable. An example of this modeling approach discussed by CEAS (1979b) is provided by Figure 2 which shows the model fit and independent test results for the Sengal rice yield model. The model is defined as:

$$\hat{Y} = 12.73 + .07 \text{ (CMR)}$$

where $\hat{Y}$ is the estimated yield in quintals per hectare and CMR is the crop moisture ratio for the growth stage from August through September.

3. Analogue Yield Models

Corn yield models developed by Leeper et al (1974) and two models developed by CEAS from Puerto Rican corn plot data were tested and parameterized for use as analogue models in the Caribbean Basin. Figure 3 represents an example of the type of testing of these models against corn plot data for Lajas, Puerto Rico, as well as the model fit for the Lajas corn yield regression model. These linear regression models require weekly precipitation, mean weekly maximum temperature, estimated corn rooting depth, and/or available soil moisture in the active rooting zone at the time of planting. All require an estimate of planting date. Based on sensitivity analysis and independent testing, two

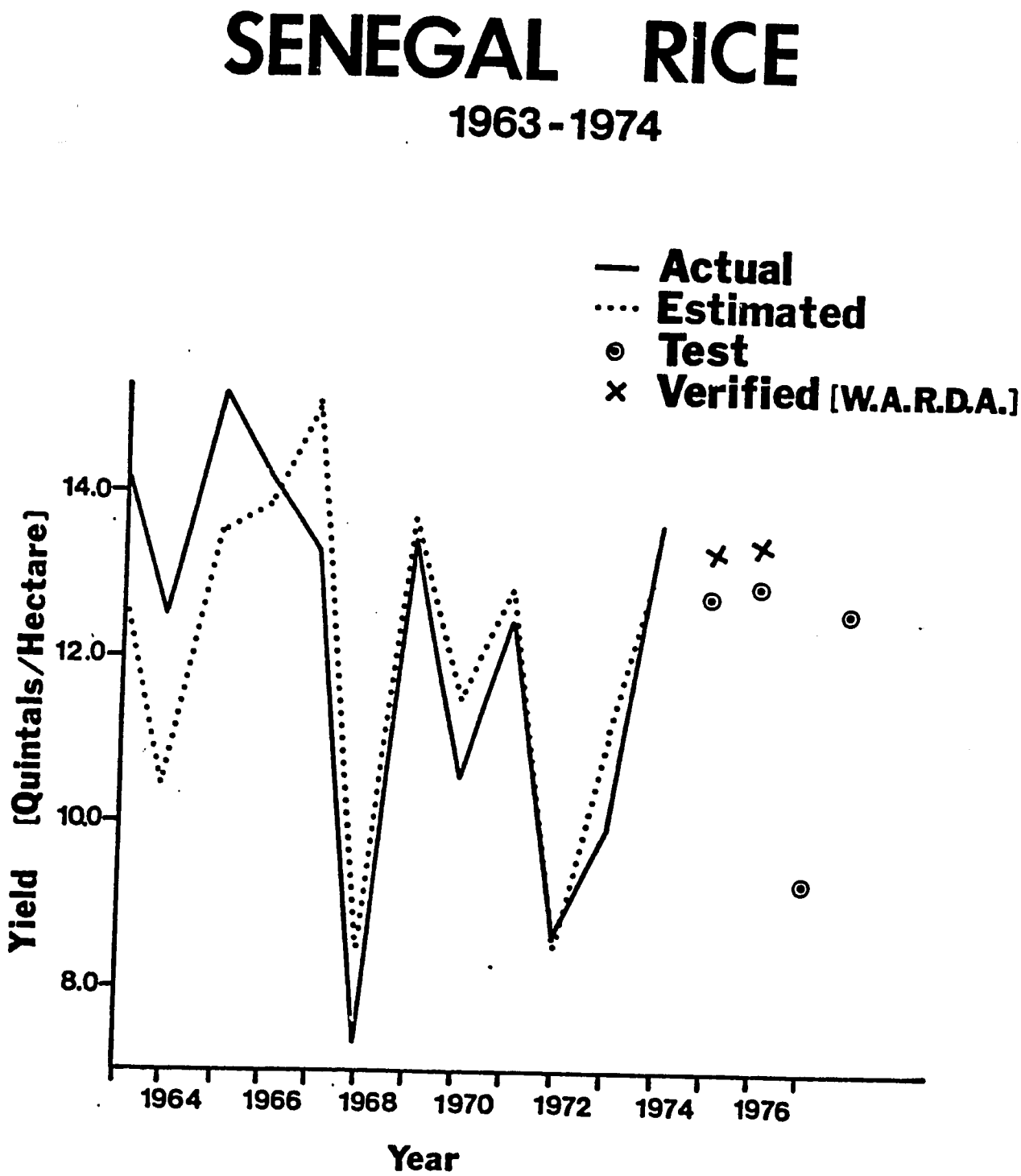

Figure 2. Senegal rice model. Independent data for 1975 and 1976 were obtained from the West African Rice Development Association (WARDA), Monrovia, Liberia. Yield estimates for 1977 and 1978 are also included. (NOAA/CEAS 1979b)

models were selected for use in Haiti, the Dominican Republic, and Jamaica to provide historical corn yield indices for the period 1920-1978. The historical indices are used to discuss the likelihood of corn crop failure and to qualitatively interpret real-time corn yield predictions.

Additionally, an analogue corn yield model was used in scenario analysis to demonstrate the negative effects of soil erosion in northwest Haiti (CEAS, 1979a). It was shown that soil erosion and the associated reduced water holding capacity has lead to "pseudo-drought" conditions, reduced potential crop yield by as much as 30 percent, increased crop yield variability by a factor of four, and increased the potential for abnormal food shortages.

4. Crop Model Indices

The previously defined Crop Repsonse Indicators were used to develop historical yield indices from climatic data for those countries with questionable crop yield data. In addition, Yao's R-index was also used to compute optimum planting dates for various crops in Haiti in order either to verify or establish regional crop calendars.

Figure 4 shows the soil moisture and yield moisture indices expressed as percentiles for corn planted in the autumn at Cap-Haitien, Haiti, during the period 1922-1977. Only relative information on potential yield due to drought can be determined from these indices, not estimates of absolute yield. In general, the indices are in very close agreement for each year; however, for other locations this is not necessarily the case. For example, similarly derived indices for corn planted at Port-au-Prince, Haiti, exhibited distinct differences for about 10 percent of the cases. Analysis suggested that soil moisture reserves in these years may have been adequate to overcome deficient precipitation at silking.

Figure 5 is an example of the use of the crop moisture ratio (CMR) for millet grown in Niger. The percentile ranking of CMR for the reproductive growth stage showed that considerably less moisture was available for crop development during the period from 1968 to 1973. The derived yield indices suggest that crop yields were below normal during these drought years. These results compared well with the traditional linear regression model developed for Niger millet.

Tables 1 and 2 summarize the crop models including indices which have been developed for the Caribbean Basin and Sub-Saharan Africa, respectively.

APPLICATION OF EARLY WARNING INFORMATION

The Early Warning Impact Assessment Reports of potential drought within the Caribbean Basin and African Sahel region have been provided by NOAA/EDIS to OFDA for distribution to State Department and AID regional bureaus, overseas missions, Food for Peace, the Sahel Development Program, FAO and other selected users on an intermittent experimental basis since 1977. This process of developing, testing and refining agroclimatic monitoring information into an operational system is part of OFDA's overall strategy to monitor all potential and actual disaster situations, including "creeping disasters" throughout the developing world.

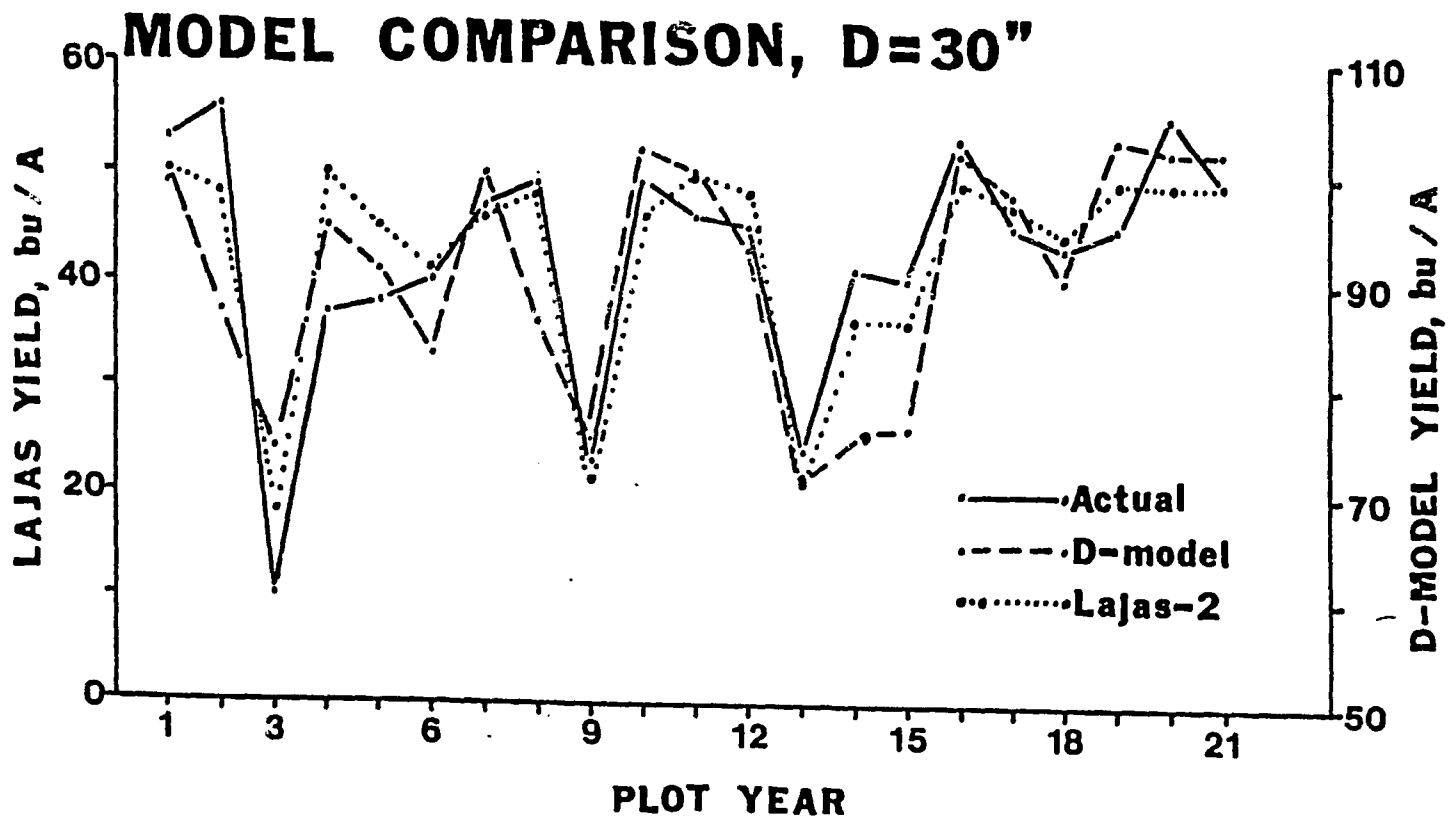

Figure 3. Comparison of actual yield at Lajas, the Lajas-2 regression model fit and the "D" corn yield model (corn rooting depth of 30 inches) where the predicted yields for the "D" model are scaled on the right vertical axis. (NOAA/CEAS, 1979 a)

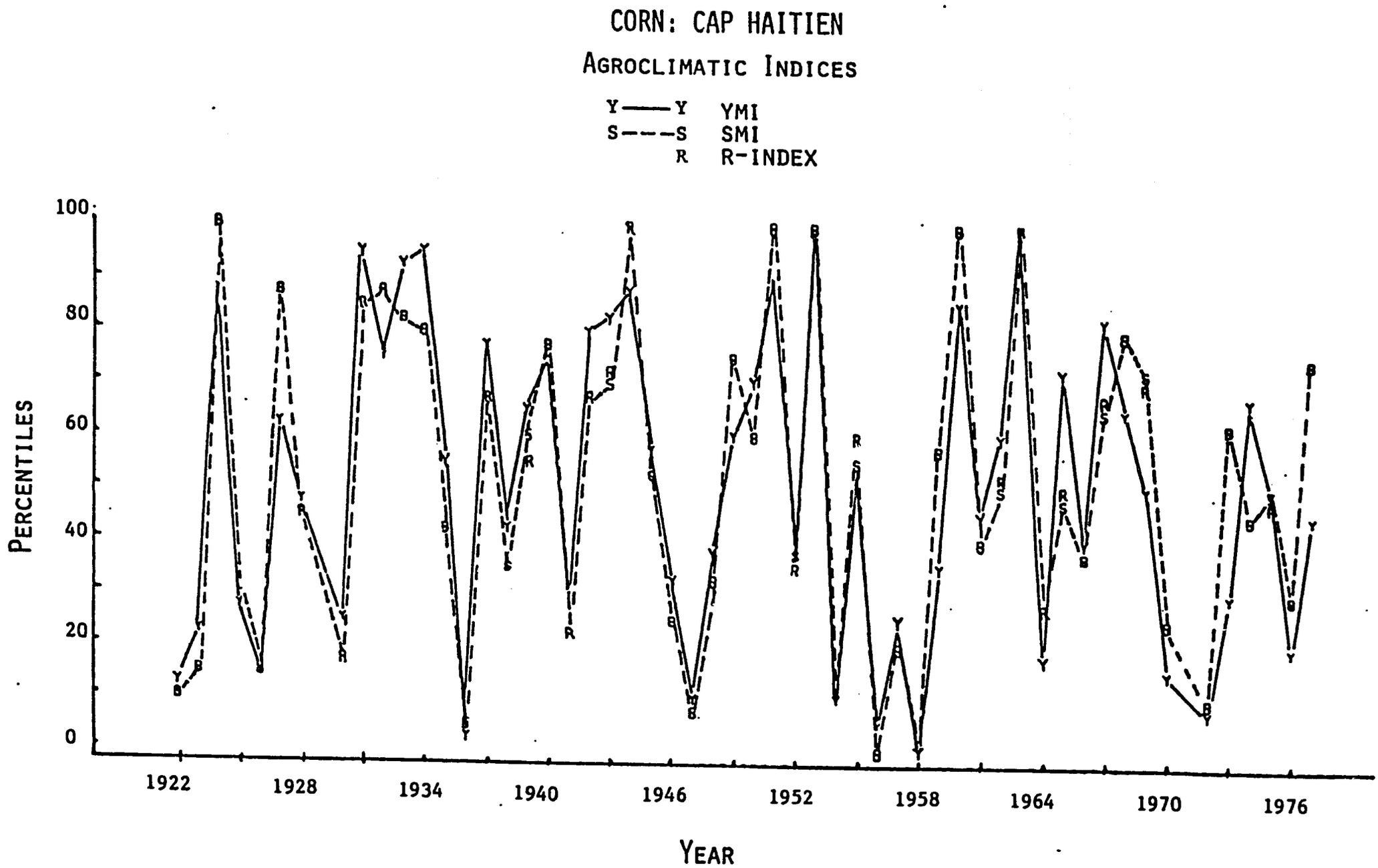

Figure 4, Historical Agroclimatic Indices for corn yield at Cap Haitien, Haiti, determined from September through November rainfall data, (NOAA/CEAS 1979a)

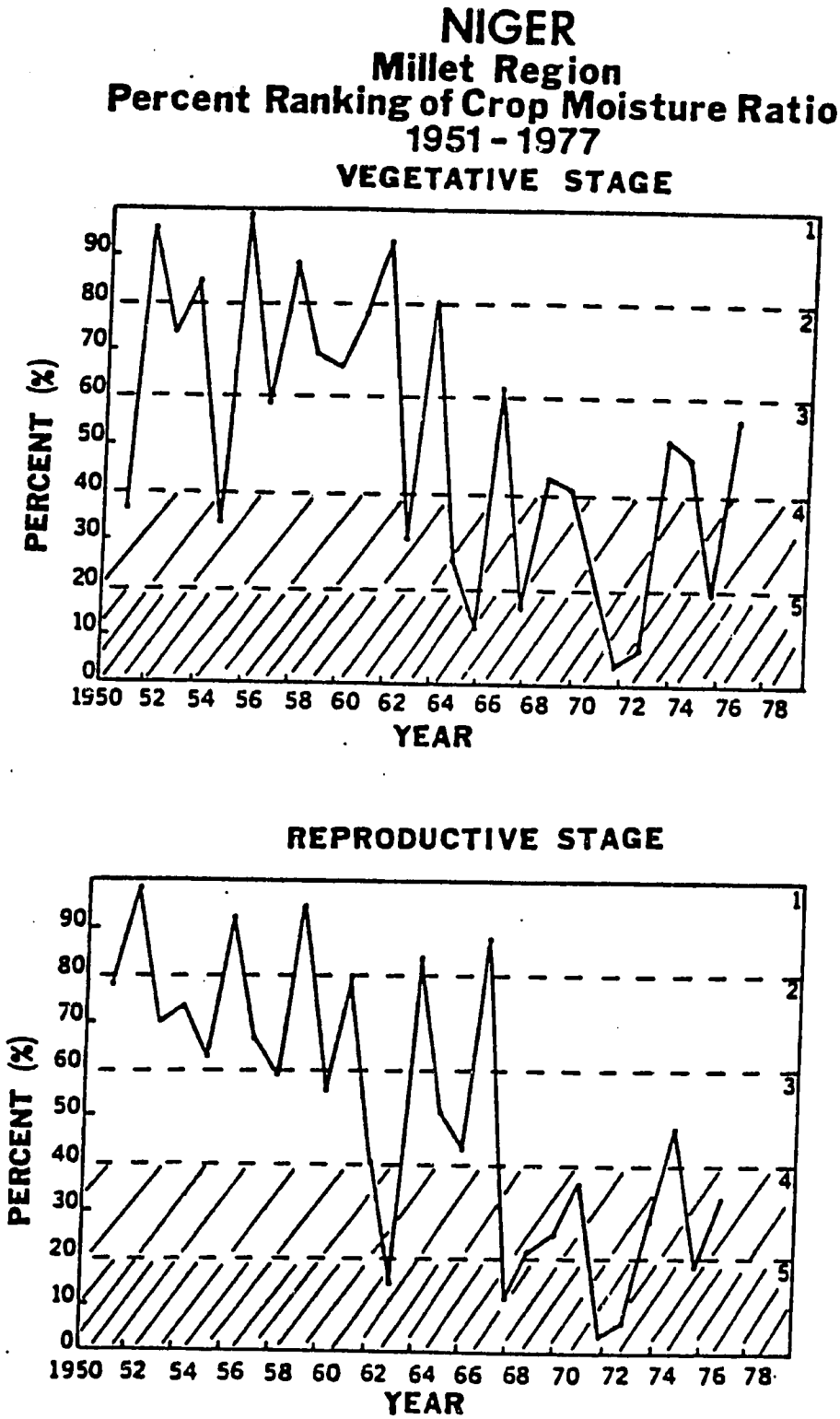

Figure 5. Historical yield indices, expressed in terms of percentile ranking of the crop moisture ratio (CMR), for both the vegetative stage (top) and the reproductive stage (bottom) of millet in Niger. The numbers on the right-hand side represent the following: 1 well-above normal; 2 above normal; 3 near normal; 4 below normal; and 5 well-below normal. (NOAA/CEAS 1979b)

TABLE 1

CROP MODELS FOR THE CARIBBEAN BASIN

Country	Number Regions	Data Base	Crop(s)
a. Regression			
Cuba	6	1950-74	Sugarcane
b. Analogue			
Haiti	1	1920-60	Rice
Dominican Republic	2	1920-78	Corn
Haiti	6	1920-78	Corn
Jamaica	2	1920-78	Corn
Haiti	3	1920-78	Sugarcane
c. Index			
Cuba	3	1950-74	Corn, Rice, Millet, Beans, Sweet Potatoes
Dominican Republic	2	1920-78	"
Haiti	6	1920-78	"
Jamaica	2	1920-78	"

Table 2. The African weather-crop yield models based on the equation: Yield in quintals/hectare $= A_o + A_1(CMR_{dfn \text{ for specific crop stages}})$.

Country	Crop	CMR_{dfn}-Variable Crop Stage	Months	A_o	A_1
Senegal	Millet	Vegetative	Jul-Aug	5.41	0.02
	Cowpeas	Vegetative	Jul-Aug	3.41	0.02
	Groundnuts	Flowering	Aug-Sept	8.14	0.04
	Corn	Veget + Flower	Jul-Sept	7.82	0.03
	Rice	Late	Aug-Oct	12.73	0.07
The Gambia*	Millet	Vegetative	Jul-Aug	5.41	0.02
	Rice	Late	Aug-Oct	12.73	0.07
Niger	Millet	Flowering	Aug-Sept	4.84	0.02
	Sorghum	Flowering	Aug-Sept	5.31	0.04
Mali*	Millet	Vegetative	Jul-Aug	5.41	0.02
	Millet	Flowering	Aug-Sept	4.84	0.02
Mauritania*	Millet	Vegetative	Jul-Aug	5.41	0.02
Sudan	Millet	Flowering	Aug-Sept	5.36	0.03
	Sorghum	Vegetative	Jul-Aug	8.04	0.03
	Sesame	Flowering	Aug-Sept	3.82	0.03
Nigeria	Sorghum	Vegetative	Jul-Aug	6.87	0.02
Chad**	Millet	Vegetative	Jul-Aug	--	--
Upper Volta **	Millet	Vegetative	Jul-Aug	--	--
	Millet	Flowering	Aug-Sept	--	--

* Analogue models.

** Assessments made based on the CMR ranking of the critical stage.

1. Program Objectives

Principle program objectives which have been met or are currently in the process of being met as the global agro-climatic monitoring system is tested and becomes operational are as follows:

a) Compilation of comprehensive historical meteorological and agricultural country-specific computerized data bases, establishment of regional crop calendars, and deliniation of the geographic distribution of crop types in cooperation with host government scientists.

b) Development and institutionalizaton of the use of statistical models to monitor and forecast relative crop yields for subsistence agriculture in the LDC's.

c) Development of assessment indicies and systems for the dissemination of drought early warning and crop yield forecast information to host government users and international organizations.

d) Provision of technical assistance to host governments and others in the interpretation, application and integration of assessment data into drought/famine decision processes, and planning and preparedness programs.

The first two objectives have been met for the Caribbean Basin and Sub-Saharan Africa, while the first objective is near completion for Southern Asia. The third objective is near completion for the Caribbean Basin and Sub-Saharan Africa, and the fourth objective is being met for selected countries in the Caribbean Basin.

Research projects are completed on the Caribbean Basin and Sub-Saharan Africa. Current efforts in these regions now concentrate on setting up an operational system through cooperative efforts of AID, NOAA, USDA and FAO. Assessments for both drought conditions and crop yields will continue through 1980 while the system is tested and evaluated. Applied research has commenced for both Southern Africa and southern Asia. These results will be incorporated in the global system as they are completed and ready for operational testing.

2. LDC Participation

LDC participation in the implementation phase of the program is of primary importance to AID, USDA and NOAA. Close collaboration between LDC agro-meteorologists, meteorologists, agronomists, agricultural scientists, statisticians, planners, and U.S. Government counterparts is essential to technology transfer objectives. Future activities will include increased data exchange and LDC counterpart training in information use, dissemination and application to drought assessment and food production problems. LDC agricultural extension officials can utilize agrometeorological information to assist farmers in establishing crop protection programs and to increase crop yields, and reduce crop loss due to incipient drought conditions or weather anomalies. These officials can utilize the agrometeorological analysis in agricultural development planning and drought famine prevention by increasing the lead time needed to make decisions concerning food aid requirements.

Additionally, LDC officials can utilize the agrometeorological assessments to establish grain reserve program strategies, improve food security, exercise seed storage options, and implement alternative crop production based on agroclimatic analyses.

3. Disaster Declaration and Relief Management

When a natural or man/made calamity strikes a foreign country, the U.S. Ambassador on the scene may determine that a disaster has occurred; that U.S. Government assistance is warranted because it is beyond the capacity of the affected country to respond to the needs of victims; that the affected country desires U.S. assistance; and that it is appropriate for the United States to respond. The Ambassador can exercise his authority to spend up to $25,000 for immediate relief. Beyond that, expenditures must be approved by AID/OFDA in Washington. Any relief activities proposed by Washington must, in turn, be approved by the U.S. Ambassador. Such coordination ensures that all U.S. Government assistance is necessary and appropriate.

Appropriate assistance depends on reliable assessment of "creeping disasters" such as drought, subsistence food shortfalls, and/or drought-induced famine. Such assessments may occur for several weeks or months eventually leading to a disaster declaration in response to a specific early warning drought assessment alert. The U.S. Ambassador's discretionary authority may be used to make a cash donation to the stricken countries' government or to the Red Cross, or to voluntary agencies already operating in that country. It may also be used as the basis for the decision to buy relief supplies locally, or to finance distribution costs, or hire local labor and equipment. Should food aid be required, P.L. 480 commodities already on hand, can be diverted for emergency purposes. Additional emergency food may be authorized by AID's Food for Peace Office.

"Creeping disasters" such as drought and abnormal food shortages of long-term nature are managed by AID. OFDA monitors the early stages of these calamities to avert famine and provide assistance that may stretch from one crop cycle to the next, or longer. If AID and other donors acts at an early stage of a slowly-developing disaster (given sufficient lead-time), human suffering can be greatly reduced and the potential for a much larger future effort may be precluded. In effect, AID could save both lives and money by optimizing decision-making based on reliable, quantitatively-based weather and subsistance crop yield information. Too often, in the past, drought conditions have been recognized and confirmed in the field only after the situation reached the crisis stage. However, with the current OFDA/NOAA/USDA cooperative effort we now have a tool to monitor potential problem areas and to provide early warning of possible food shortages, so that a more timely, cost effective and well planned assistance program can be established and coordinated. AID Mission personnel are alerted by cable and frequently are able to provide supplemental on-site information. CEAS meteorological and agronomic data bases can also be shared with USAID Missions for long-term development assistance planning and program design considerations, especially with respect to managing food production problems.

4. International Cooperation

AID/OFDA, NOAA and USDA are working to integrate the results of this program into the FAO global monitoring and early warning system on food and agriculture. (FAO is designing a system analogous to the AID/NOAA system.*) In addition, an Interagency Agroclimatic Monitoring Working Group consisting of AID/OFDA, NOAA/EDIS, and USDA staff has been established and begun contact with FAO and other international organizations to assist in disseminating research results, evaluating pre-operational weather/crop assessment reports, and establishing the institutional mechanism for operational assessment reporting.

AID/OFDA has increasingly developed confidence in the weekly weather assessment reports based on preliminary performance. These reports are currently utilized in decisions concerning food aid and disaster relief. If this system had been in place before such tragic events as the 1973-75 Sahelian drought, we believe there could have been considerable savings in suffering and resources. Use of the system to date has resulted in earlier shipments of food, improved efficiency in planning and implementing emergency operations, and increasing confidence in the ability to deal with the many food production shortfall emergencies that arise annually. The AID African Bureau in 1978/79 designed and implemented a highly cost-effective drought emergency program for the Sahel, largely on the basis of the NOAA/EDIS weekly African Weather Assessments. The use of these reports, both in Washington and in the field, has begun to enhance AID contingency planning decisions. For example, in March 1980, AID's African Bureau established a working group to develop and implement a systematic report and analysis capability to ensure timely review of drought, famine and food scarcity problems as they develop on the entire African continent. Information and data are collected from all possible independent sources including the CEAS Early Warning Assessment Reports. Additionally, USAID field missions often report to Washington the following information: crop failures, livestock deaths, drought, sudden price changes for foodstuffs, unexpected fluctuations in food imports or exports, increases in malnutrition cases coming to the attention of local clinics and doctors or observed during field trips, and opinions of Government officials, and other donor agencies on current crop conditions, livestock conditions (where applicable), abnormal weather conditions, weather "prediction" based on observations, significant increases in infant mortality (especially if traceable to malnutrition) and food export or import trends. This information is being analyzed by NOAA/CEAS, in a continuing effort to verify reliability and performance of the crop models and weather assessments.

VERIFICATION OF CEAS EARLY WARNING ASSESSMENT SYSTEM

Currently being addressed is the task of providing a suitable verification of the CEAS Early Warning System performance. To accomplish the verification it will be necessary to establish an acceptable performance record subject to available data. Data for verification are now being sought from a number of sources. The verification efforts will take two forms. First, a qualitative evaluaton based on information extracted from program records maintained by in-country experts such as private volunteer organizations, WMO, FAO, AID and USDA reports. Second, reliable yield data will be used to verify the model performance where it is available. In most cases however, the yield model performance can only be evaluated by qualitative data. For example, preliminary verification of crop indices for Haiti suggest proposed categories

*Frere & Popov,1977.

for relative yield indices of above average, average, below average, and inadequate subsistence food supplies where relative yield information is expressed in percentile ranges as follows:

Percentile Range	Qualititative
0-20.	Inadequate (Severe drought-potential abnormal food shortage)
21-40.	Below Average (Moderate drought impact)
41-80.	Average
81-100	Above average

Verification procedures emphasize the ability to identify those years in which inadequate and below average food supplies exist. Less importance is being placed on the non-critical categories ranging from 41-100 percent..

The R^2 (explained variance) is a general measure of the potential model performance. The NOAA/CEAS linear regression type has the general form:

$$\hat{Y} = \text{constant} + \text{technology} + \text{weather effects.}$$

In this form, it is important to know and understand the contribtuion of each term.

The contribution of each term to the overall explained variance has been determined for the United States agro-climatology (Haigh 1977) as follows:

CROP	TECHNOLOGY	WEATHER
Wheat	51.2-67.9%	5.2-21.9%
Soybeans	53.7-72.1%	14.8-33.2%
Corn	67.4-78.0%	9.7-25.3%

In contrast to the above, the contribution of weather to the R^2 of models developed for LDC's agroclimatic regimes increases over the the more semi-arid regions of the world and in particular, developing countries where the level of applied technology is minimal. For example, 10 regression type models were developed for Sub-Saharan Africa, where the explained variance (R^2) ranges from 52 to 76 percent and is totally due to weather effects.

Verification is expected to become easier in the future as the concept of area frame sampling techniques are introduced through the cooperative assistance programs such as those sponsored by AID in cooperation with the U.S.D.A in selected countries of the Caribbean, Africa and South and Southeast Asia. When the development phase is completed, crop yield statistics, which are potentially compatible with those currently published by USDA for the U.S., are expected to be available for several developing countries covered by the NOAA/AID program.

A question not easily addressed at this stage of test and evaluation is related to the benefits to be derived from early or mid-versus-late season subsistence crop yield estimates. When considering weather events and their impact on crop yield potential, it is important to realize the limits of the models being used. These crop yield models are not designed to forecast the impact of future weather on crop production. The models are designed to evaluate only the cumulative impact of climate on potential yield up to the time that the estimate is made, i.e., a measure of the climate-related plant stress in terms of reduction in potential yield. At a future time, a hail storm, freeze, flood or high winds can quickly change a bright outlook into a local or regional disaster. It is imperative that these limits are adequately considered when using the early or mid-season yield assessments. It is, however, a fact that given favorable (unfavorable) climatic conditions through the reproductive growth stage of the crop that the probability of experiencing good (poor) crop yields is increased. Therefore, more confidence can be placed on late season forecasts. The probability of a good yield does not reach 100 percent until the crop has been harvested.

Some preliminary results from the test and evaluation are as follows:

1. Caribbean Basin

Monthly assessment reports were prepared at the end of each month during the autumn crop growth season (August-December) for 1979. (A special report in August 1979 summarized the end-of-season conditions for the 1979 spring crop season.)

Climatic conditions in the Caribbean Basin were generally favorable during 1979 except possibly during the autumn for some regions in Haiti and Jamaica. Marginal crop conditions due to minor drought were noted in the model assessment report contained in the December 31, 1979-January 6, 1980 issue of Caribbean Basin Weekly Weather Assessment as follows:

> "Below normal rainfall has been observed in the northern (Region 2) and southwest (Region 6) sides of Haiti and in Jamaica during part of October, November and December. There is indication of crop damage in these regions, particularly for beans (red and kidney). For Jamaica and southwest (Region 6) side of Haiti, the yield indices indicated a considerable decline in yield as compared with 1978 yield levels. Crop conditions are believed to be at below normal conditions due to water shortages during the reproductive stage, particularly for late plantings."

The mean percentile rank of crop indices for autumn corn, rice and beans was 35 in both northern and southwest Haiti while the percentile range of indices for Jamaica was 25-30, indicating more adverse conditions. These model results suggested the potential for reduced yields due to moderate, regional drought. (A dry, 1980 spring in these same regions would be of concern due to the marginal autumn conditions.) Analysis has shown that crop index values below the 20th percentile are frequently associated with severe drought and potential food shortages in Haiti.

A major effort currently in progress is the verification of the agroclimatic crop indices, particularly those used in Haiti, a data-limited country. The report, "Drought/Food Production Problems in Haiti: Case Study for 1978" by Ravelo (1980) discusses this analysis in detail for a year when drought-related, abnormal food shortages existed in northwest and southwest regions of Haiti.

Figure 6 was contained in the above report and illustrates corn crop conditions as depicted by the Yield Moisture Index for Corn (YMI) in Haiti following the reproductive growth stage, November 1978. In this example, the YMI is expressed as a departure from normal conditions. The critical value, of -60 percent below normal was determined by comparing percentge departures of the YMI to historical percentile ranks for the same index at several locations when abnormal food shortages were known to exist.

Figure 6 indicates the critical zones where severe corn crop stress existed following the reproductive growth stage (i.e., silking) in 1978. The regions near Jeremie in southwest Haiti and both Jean Rabel and Limbe in northwest and northern Haiti, respectively, were especially hard hit by drought. Documented reports from CARE and other private volunteer organizations as discussed by the Department of State,1979confirmed the serious nature of the drought impact and related abnormal food shortages in these regions. This index could be expected to reliably provide about 30 days early-warning prior to actual maturity of the crop. At least in this example, the YMI for corn provides more precise information on the locations of most serious concern to decision makers than just an analysis of monthly rainfall departures from normal. For example, Figure 7 shows a very broad region in northwest Haiti for the zone of 60 percent below normal rainfall in November, 1978.

A literature review and expert opinion survey has resulted in the identification of several examples of abnormal food shortages in Haiti during the past 30 years. (It has to be assumed that in general only major problems find their way into the literature.) In most instances severe drought precedes abnormal food shortages. Documented drought/abnormal food shortages include 1947/48, 1956-58/59, 1967/68, 1970, 1973, 1974-75/76, 1977, and 1978. These examples are directly associated with YMI percentile values of 1-20 for corn, millet, beans, and rice in the affected regions. There is evidence that disastrous food shortages in the Northwest Department of Haiti are most probable if a dry spring follows a dry autumn, the major crop season.

2. Sub-Saharan Africa

Monthly assessment reports were issued at the end of August, September, and October, 1979. In addition to the models listed in Table 2, a rangeland index was also computed for the 1979 season in the northern Sahel zone. Table 3 presents the regression model forecasts which were included in the October 1979 Model assessment report submitted by CEAS. The concluding remarks contained in the October 1979 report include:

"October marks the end of the growing season in the Sahelian countries of Africa. The overall assessments of Sahelian agriculture are below normal in all countries. Seasonal rainfall for 1979 was below normal but not severely lacking; however, most crops were subject to water stress conditions during August from low rainfall. These moisture stress conditions during the reproductive stage may have seriously reduced crop yields and rangeland production.

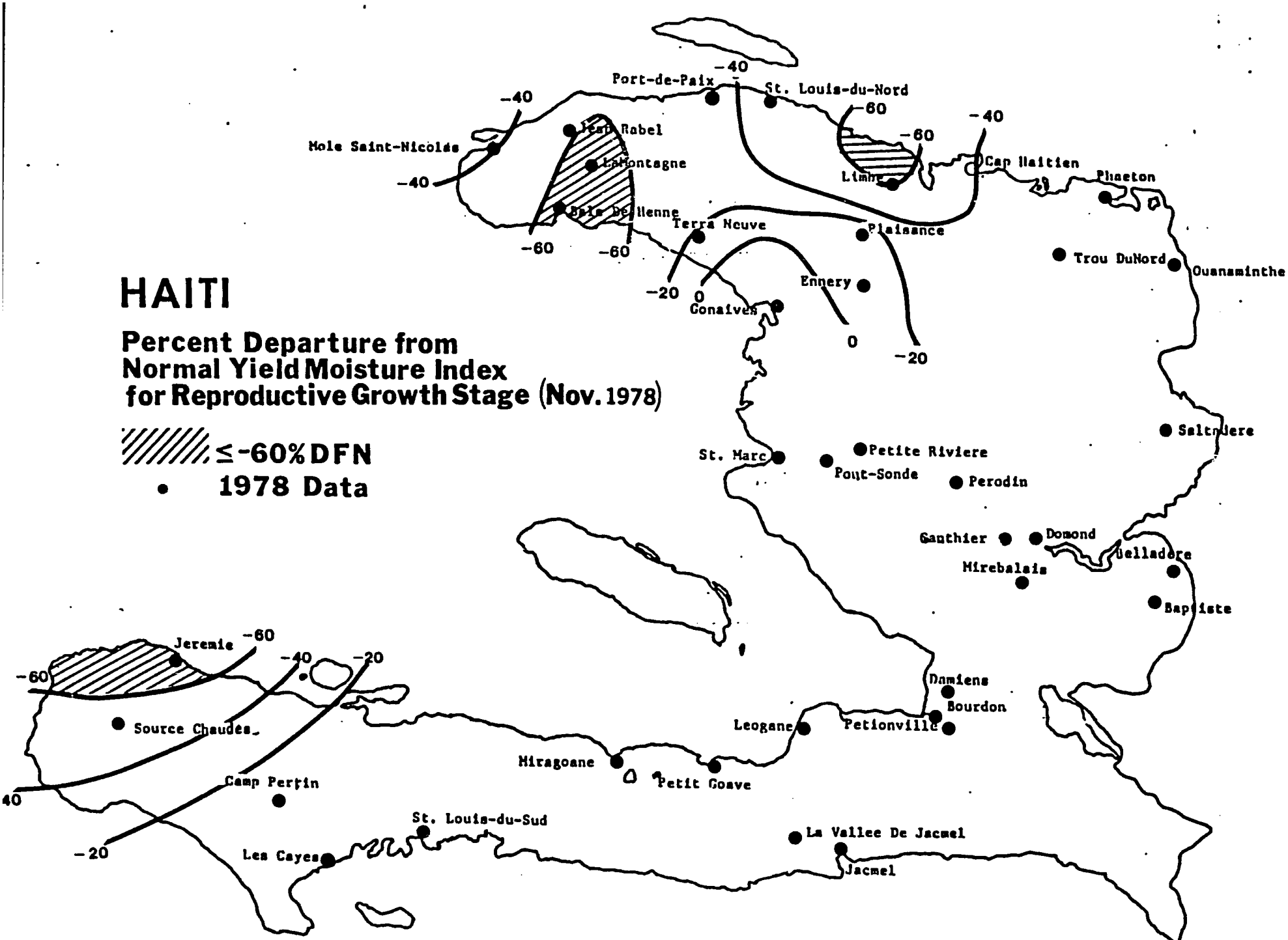

Figure 6. Yield Moisture Index for corn following the reproductive growth state (silking) November 1978. The critical value, of -60 percent below normal was determined from historical percentile ranks for the index at several locations.

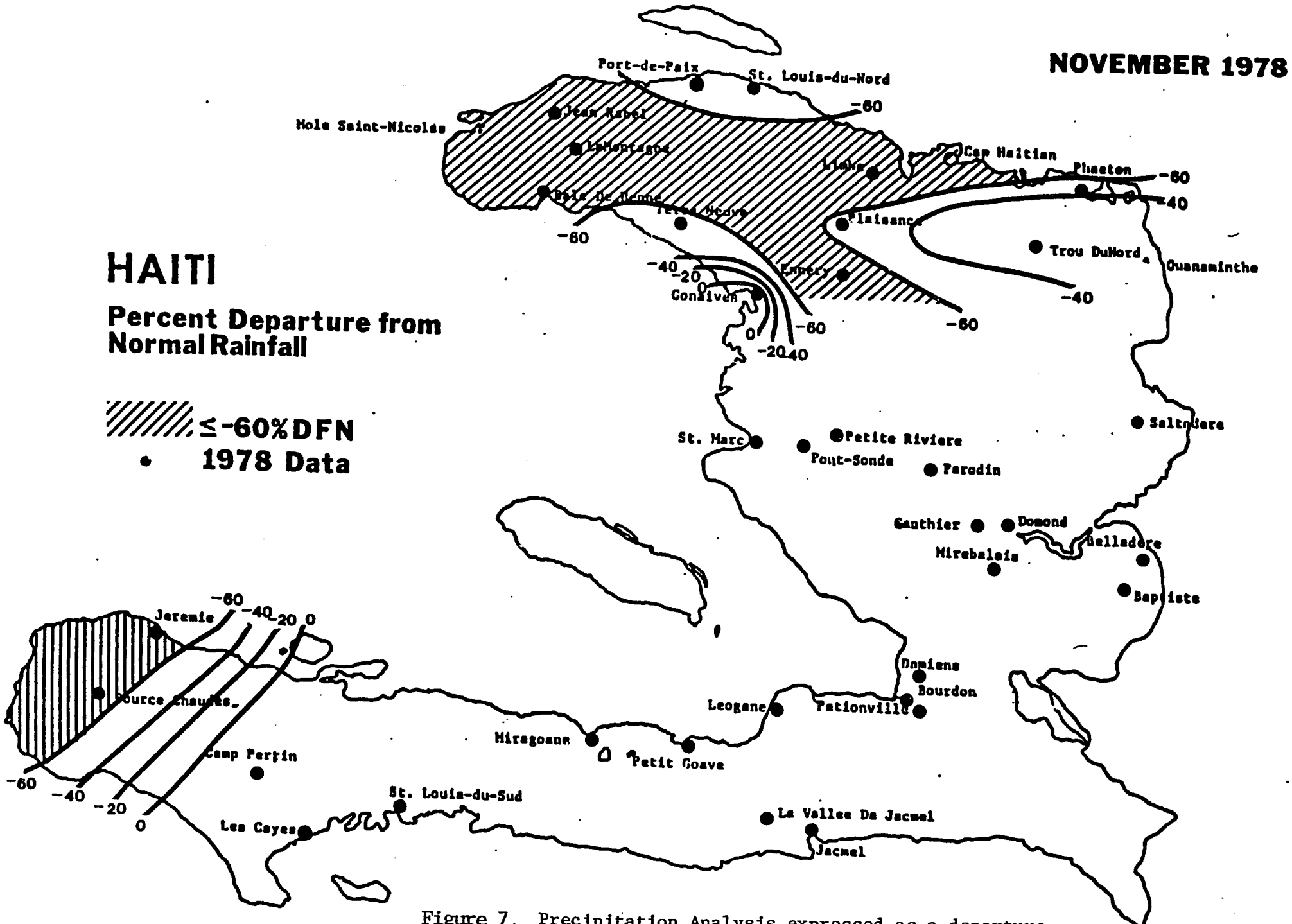

Figure 7. Precipitation Analysis expressed as a departure from normal for November 1978.

In general, there is a negative departure from 1978 crop conditions at all growth stages. The model yield estimates for selected crops ranked very low as compared with previous years."

The report, "Evaluation of the 1979 Growing Season in the Sub-Saharan Countries as Determined from CEAS Assessment Tools," by Dale (1980) represents a country-by-country case-study analysis of the agroclimatic conditions. In addition to discussing the models (regression, analogue, and CMR indices), the report addresses the quality of the rainfall data received during 1979, as well as a comparative analysis with FAO reports issued on September 4 and 21, October 19, and November 7, 1979, plus the January 18, 1980 FAO report.

Table 4 represents a summarization of the results for all of the CEAS models for all crops used in each country and displays these results in percentiles (0-100) by crop growth stage, i.e., planting, vegetative, and flowering. (Based on an analysis of historical data, percentiles in the 0-30 range are believed to represent severe crop damage due to moisture stress.)

In general, conditions for planting were favorable; however, conditions rapidly deteriorated by the growing (vegetative) crop stage and thereafter. The results presented in Table 4 were found to be in very close agreement with FAO reports (only statements on climate impact were considered as FAO also reports adverse conditions due to factors other than climate).

Both the CEAS Models and the FAO reports for this particular year provided useful early-warning information on potential crop failure as early as the end of the vegetative growth stage which is generally 60 days prior to harvest. In general, crop model results indicating crop damage due to drought during the critical flowering stage would be highly indicative of final crop yield. In this situation, more confidence could be placed in the crop forecast at the end of the reproductive stage. Therefore, at least 30 days early warning prior to harvest could be anticipated.

In summary, the results of the model test and evaluation for the 1979 season have been highly encouraging; however, it must be noted that these models can only detect climate impact due to drought as represented by monthly data. Also, the models are not sensitive to either non-weather events or short-term weather events of an episodal nature. Some episodal data including examples of abnormal food shortages have been used to verify, scale, and verify crop model indices.

TABLE 3.

Model estimates expressed as 1979 Ranking (%) based upon growth-stage, Crop Moisture Ratio (CMR) at the end of October 1979.

Period:

COUNTRY	CROP	CMR (Growth Stage)	RANKING (%)
SENEGAL	CORN	Vegetative-Flowering	10
	MILLET	Vegetative	10
	RICE	Late	5
	GROUNDNUTS	Flowering	5
	COWPEAS	Vegetative	10
NIGER	MILLET	Flowering	5
	SORGHUM	Flowering	5
SUDAN[1]	MILLET	Flowering	5
	SORGHUM	Vegetative	20
	SESAME	Flowering	20
NIGERIA	SORGHUM	Vegetative	*
THE GAMBIA	RICE	Late	5
	MILLET	Vegetative	15
CHAD[1]	MILLET	Vegetative	5 (Yield Indices)
MAURITANIA	MILLET	Vegetative	5
UPPER VOLTA	MILLET	Vegetative Flowering	5 10 (Yield Indices)
MALI	MILLET	Vegetative Flowering	5 5

LEGEND 1 A single monthly satellite estimate was used in the assessment.
* Meteorological data is not available for model estimate.
** Primary reporting station missing.

Prepared by NOAA/Center for Environmental Assessment Services.

TABLE 4.

SUMMARIZATION OF ALL CEAS CROP
MODEL RESULTS IN PERCENTILES BY COUNTRY AND
CROP GROWTH STAGE AT THE END OF THE GROWING SESAON
IN 1979 FOR SUB-SAHARAN AFRICA COUNTRIES

Country	Planting (June)	Growing (Jul/Aug)	Flowering (Aug/Sept)	Ripening (Sept/Oct)
Senegal, N.	80	10	5	5
Senegal, S.	85	15	5	5
The Gambia	95	25	5	5
Mauritania	75	10	15	10
Mali	10	5	5	20
Upper Volta	85	5	10	5
Niger	80	15	15	10
Chad	15	5	5	5
Sudan	70	10	15	20

SUMMARY AND CONCLUSION

The need for an early warning tool has been clearly established. The AID/OFDA developmental work completed by NOAA/CEAS's Climatic Impact Assessment Division for the Caribbean Basin and Sub-Saharan African countries is now being operationally tested with the goal of establishing an acceptable track record of performance. (Results for both regions have been highly encouraging.) A task to verify the probable performance in past years, using historical climate-based crop yield indices, will be completed by January, 1981. A similar project is underway for southern Asia. A project for crop yield model development for Africa, south of the Sahel Region is under consideration.

Significant interaction has already taken place with representatives from the developing countries and the CEAS staff through participation of CEAS staff at AID-sponsored Disaster Preparedness Seminars. Selected agrometeorology staff from developing countries have undergone training at the CEAS facilities in Early Warning Assessment preparation and Yield Model Development. The WMO and FAO have participated in the exchange and development of the data needs and weekly assessment publications.

Through cooperative efforts between USDA and AID, assistance to establish an area frame sampling program in developing countries has been started. This will eventually enable CEAS to establish a more rigorous performance evaluation for the early warning program.

The AID/OFDA Early Warning System, as a tool for use in planning responses to potential areas needing assistance, has already been proven useful and appears cost-effective. The full potential value of the system must, however, await an evaluation of the effectiveness of AID's disaster relief actions and future response to "creeping" disaster assistance needs.

ABSTRACT

Disaster assistance can be most effective only when all its components operate efficiently. An alert or early warning indicator is a critical initial stage leading to a timely U.S. response. Without an early warning, effective and rapid responses to minimize human suffering become increasingly more difficult. AID's Office of U.S. Foreign Disaster Assistance (OFDA) has operationally benefited from the Center for Environmental Assessment Services Early Warning Program, developed by the Climatic Impact Assessment Division (CIAD), of the Environmental Data and Information Service's Center for Environmental Assessment Services. The CEAS Early Warning Program uses the combination of climatic information, real-time synoptic data, satellite photos and other ancillary data to monitor climatic anomalies. In addition, climate/crop yield models including agroclimatic indices have been developed to provide information on either relative or absolute crop yield.

The aberrations or departures from average conditions are interpreted for impact on potential subsistence food supplies for the developing countries. The CEAS Early Warning Assessments provide AID/OFDA with an alert of potential problems as theydevelop, and allow OFDA the opportunity to plan for such contingencies as may be required to develop a disaster assistance program in a timely and efficient manner. The implications of the OFDA reaction to an early warning alert will be examined.

Synoptic data is routinely collected for CEAS from over 8,000 stations around the globe at the National Meteorological Center (NMC), Camp Springs, Maryland. The temperature and precipitation data are analyzed for quality control, summarized and plotted in terms of departures from normal, cumulative departures and frequency of days reporting precipitation. Techniques that have been developed to estimate precipitation amounts from Geosynchronous Observational Environmental Satellites (GOES) Visible and Infrared (IR) imagery for data deficient regions will be discussed. Subsistence crop yield model estimates which are used as tools to indicate potential crop response to observed climate will be evaluated.

REFERENCES:

CEAS 1979a, A Study of the Caribbean Basin Drought/Food Production Problem; Final Report. Climatic Impact Assessment Division-Models Branch of NOAA and University of Missouri-Columbia, Atmosheric Science Department. - May 1979.

CEAS 1979b, Weather-Crop Yield Relationships in Drought-Prone Countries of Sub-Saharan Africa.; Climatic Impact Assessment Division Models Branch of NOAA and University of Missour-Columbia, Atmospheric Science Department. Final Report - July 1979.

Dale, J. 1980, Evaluation of the 1979 from Growing Season in Sub-Saharn Countries as Determined from CEAS Assessment Tools, NOAA/ EDIS /CEAS and UMC Progress Report. February, 1980.

Department of the State, 1979; American Embassy, Port Au Prince, Cable P 121511Z, Feb., 1979 (Report on Dry Weather Conditions).

Doorenbos, J. and W.O. Pruitt, 1977: Guidelines for Predicting Crop Water Requirements. FAO Irrigation and Drainage Paper 24, Rome, 144 p.

Frere, M. and G. Popov, 1977: "A Program for Monitoring Crop Conditions and Crop Forecasting in the Sahelian Region." FAO Special Report AGP:Ecol/9, 9 p.

Follansbee, W., "Estimation of Average Daily Rainfall from Satellite Cloud Photographs", NOAA Tech Memorandum NESS 44, Jan. 1973.

Leeper, R. A., E. C. Runge, and W.M. Walker, 1974: "Effects of Plant-Available Stored Soil Moisture on Corn Yields," Agron. J., 66, 723-733.

Motha, R.P., and N.D. Strommen, 1979: "Crop Yield Model Performance for Sub-Saharan Africa", Paper Presented at 8th Bio-Meteorological Congress, Shefayim, Israel, Sept. 9-14, 1979.

Motha, R.P. and C.M. Sakamoto, 1979:"The Performance of Crop Yield Models in Drought Prone Countries of Central Africa,"paper presented at 71st Annual Meeting of the American Society of Agronomy, Ft. Collins, Colorado, Aug. 5-10, 1979.

Palmer, W.C., 1965: Meteorological Drought. Res. paper 45, U.S.W.B., U.S. Department of Commerce, 58 p.

Ravelo, A.C. and W.L. Decker, 1979: "The Probability Distribution of a Soil Moisture Index," Agric. Meteorology, Accepted for Publication.

Ravelo, A.C., 1980: "Drought/Food Production Problems in Haiti: Case Study for 1978" NOAA/EDIS/CEAS and UMC Progress Report, April.

Richards, F. and P. Arkin, 1980: "On the Relationship between Satellite-Observed Cloud Cover and Precipitation", submitted for publication in Monthly Weather Review.

Steyaert, L.T., S.K. LeDuc, C.M. Sakamoto, and N.D. Strommen, 1979a: "Inadvertent Climatic Change: Investigating the Coincidence of Deforestation, Inadequate Soil Conservation Practices, Erosion, and Disastrous Food Shortages in Northwest Haiti." Paper presented at the Seventh Conference on Inadvertent and Planned Weather Modification, Banff, Alta, Canada, October 8-12, 1979.

Steyaert, L.T., 1979a: "Rainfall Analysis and Crop Yield Estimation," paper presented at the Caribbean Disaster Preparedness Seminar, St. Lucia, West Indies, June 10-20, 1979.

Steyaert, L.T., 1979b: "Experiences with Famine in Haiti," paper prsented at the Working Group on Food Security, The East/West Center, Resource Systems Institute, Honolulu, Hawaii, June 20-30, 1979.

Steyaert, L.T., R.P. Motha, A.C. Ravelo, V.R. Achutuni, S.K. LeDuc, C.M. Sakamoto, and N.D. Strommen, 1979: "Operational Decision-Making and Verification for Disaster Relief Utilizing Meteorological/Statistical Techniques for Developing Countries," paper presented at the Sixth Conference on Probability and Statistics in Atmospheric Sciences, October 9-12, 1979b:Banff, Alberta, Canada.

Yao, A.Y.M. 1969: "The R-Index for Plant Water Requirement," Agric. Meteorology, 6, 259-273.

A three day national conference to aid decision-makers who must deal with climatic uncertainty

CLIMATE AND RISK

May 27–29, 1980. Sponsored by the Center for Advanced Engineering Study at the Massachusetts Institute of Technology in cooperation with the *Panel on the Effective Use of Climate Information in Decision Making* of the Climate Research Board

-33

Thursday Morning, May 29

Session V-A Climate and Investment Decisions
Session Chairman: John S. Perry

9:00– 9:55 "Extreme Wind Speeds and Structural Failure Risks"
Emil Simiu
National Bureau of Statistics

10:00–10:15 Coffee Break

10:15–10:55 "A Climatic Data Base for the Tennessee Valley"
Peter I. Finsen
Tennessee Valley Authority

11:00–12:00 "The Value of Remotely Sensed Ocean and Arctic Region Data for Marine Transportation"
Bernard P. Miller
S. W. McCandless
ECON, Inc.

Session V-B Drought Risks
Session Chairman: Robert G. Fleagle

9:00– 9:55 "Drought Risk and Response: The Great Plains of North America as a Case Study"
Norman J. Rosenberg
University of Nebraska at Lincoln

10:00–10:15 Coffee Break

10:15–10:55 "Early Warning Assessments of Drought Used by the U.S. Agency for International Development"
Paul F. Krumpe
U.S. Department of State
Norton D. Strommen
Malcolm Reid
National Oceanic and Atmospheric Administration

11:00–12:00 "Agricultural Drought Assessment by Daily Soil Moisture Predictions"
Keith E. Saxton
U.S. Department of Agriculture

Thursday Afternoon, May 29

Session VI-A Climatic Risks of Energy Production
Session Chairman: Robert M. White

1:00– 1:55 "Economic and Social Aspects of CO_2 Increase"
Thomas C. Schelling
Harvard University

2:00– 2:15 Coffee Break

2:15– 2:55 "The Risks of Fossil Fuels and Atmosphere CO_2"
Ralph M. Rotty
Oak Ridge Associated Universities

Session VI-B Climatic Risks and Watershed Management
Session Chairman: John Waelti

1:00– 1:55 "Management of the Columbia River Watershed"
Robert G. Fleagle
University of Washington
Allan H. Murphy
Oregon State University

2:00– 2:15 Coffee Break

2:15– 2:55 "Management of the Colorado River Watershed"
Charles W. Howe
University of Colorado
Allan H. Murphy
Oregon State University

Session VII (Plenary) Review and Conclusion
Session Chairman: Myron Tribus

3:00– 4:30 Concluding Address
Sylvan W. Wittwer
Michigan State University

THINGS YOU SHOULD KNOW...

Time and Place
"Climate and Risk" will take place in the Potomac Ballroom at the Key Bridge Marriott Hotel in Arlington, Virginia from May 27–29, 1980. The conference will begin at 9:00 Tuesday morning.

Registration Fee
The registration fee of $180.00 per person includes all seminar materials and admission to all of the sessions.

Food Services
Three restaurants are located in the hotel: The Fairfield Inn and The Veranda located on the first floor of the hotel, and The View offering rooftop dining.

Optional Wednesday Dinner
If you have previously signed up for the special informal dinner, please inquire at the registration desk for further information.

Parking
A parking garage and outdoor spaces provide free parking for attendees of the conference.

Information Area
A message center will be located in the outside lobby of the Potomac Ballroom throughout the conference. Please check the bulletin board periodically for any late information about the program or any phone calls you may have received. Anyone trying to contact you may dial the hotel directly at 703-524-6400 and ask for the extension given at the registration table.