Technical Paper

Long-range Climate Forecasts for Agriculture and Food Security

Extreme Climate Events Program

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Long-range Climate Forecasts for Agriculture and Food Security

By

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Abbreviations and Acronyms

ADPC	Asian Disaster Preparedness Center
ASEAN	Association of South East Asian Nations
ASMC	ASEAN Specialized Meteorological Centre
BMG	Bureau of Meteorology and Geophysics (Indonesia)
BOM	Bureau of Meteorology (Australia)
BPPT	Agency for the Assessment and Application of Technology (Indonesia)
CLIMAG	Program on Climate Prediction and Agriculture
ECE	extreme climate event
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
FMS	Fiji Meteorological Service
HMS	Hydro Meteorological Services (Vietnam)
IMD	India Meteorological Department
IRI	International Research Institute for Climate Prediction (USA)
ITCZ	Inter-Tropical Convergence Zone
LAPAN	National Space Center (Indonesia)
MFA	most favorable areas
MSA	most severely affected areas
NRC	National Research Council
LRF	long-range forecast
PAR	Philippine Area of Responsibility
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Service Administration
SOI	Southern Oscillation Index
SST	sea surface temperature
START	System for Analysis Research and Training
TOGA	Tropical Ocean and Global Atmosphere Program
UK	United Kingdom

About the Report

This paper was presented at the *Asia-Pacific Conference on Early Warning, Prevention, Preparedness and Management of Disasters in Food and Agriculture*, organized by the Food and Agriculture Organization of the United Nations in Chiang Mai, Thailand from 12-15 June 2001. The paper is based on information collected and analysis undertaken by ADPC's Extreme Climate Events (ECE) Program.

Launched in 1998, the ECE Program is designed to improve understanding of the impacts of extreme climate events such as El Niño and La Niña on society and the environment in selected Asian countries, and to reduce the disaster impacts of such events through effective application of climate information. In its first phase (1998-2001), the ECE Program was implemented in Indonesia, the Philippines and Vietnam, and in its planned next phase, will be extended to Bangladesh and Thailand. The program is funded by the United States Office of Foreign Disaster Assistance (OFDA) and supported by NOAA's Office of Global Programs.

Abstract

It has long been recognized that if society could have advance information on weather, the adverse effects associated with it could be minimized. Prevalence of traditional forecast practices in various parts of the world reflects the demand for long-range forecasts to manage uncertainties associated with climate variability. Recent advancements in climate prediction promise huge benefits for society. However, 1997-98 El Niño management experiences reveal that a large gap exists between potential value of forecast information and the actual utilization of this information for managing agricultural systems for societal benefits. There is a need to take concerted efforts to address these gaps to take full advantage of climate prediction advances.

This paper focuses on issues relating to the evolution of long-lead forecasting over a period of time in the Asia-Pacific monsoon region, recent advances in ENSO prediction and its potential value for managing agricultural systems. The paper, while drawing experiences from the application of long-lead forecasts in recent years, also highlights emerging issues for future action.

Introduction

While climate variability-associated impacts on crop production vary from year to year, there has been a significant increase in crop production loss during certain years due to the occurrence of extreme climate events. For instance, in Indonesia, the rice crop area affected by drought during 1997-98 extended up to 867,997 ha, resulting in a loss of around three million tons (Government of Indonesia, 2000). The reduced rice production coinciding with an economic crisis led to a 300% increase in the price of rice. The Government of Indonesia imported around five million tons of rice in order to maintain price levels and ensure food security to a substantial number of households (ADPC, 1998). In the Philippines during 1997-98, drought affected 600,000 ha of rice and corn land, resulting in a loss of around 1.2 million tons of food grain (ADPC, 1997). In Fiji, 50% of the annual sugarcane production was lost, affecting 200,000 farmers during 1997-98 (Kaloumaira, 2001). In Bangladesh, a severe flood in 1998 caused crop loss of around 2.2 million tons, affecting 25 million people (FAO, 1998).

It has long been recognized that if society could have advance information on weather, the adverse effects associated with it could be minimized. Prevalence of traditional forecast practices in various parts of the world reflects the demand for long-range forecasts to manage uncertainties associated with climate variability. Recent advances in climate prediction promise huge benefits for society. However, 1997-98 El Niño management experiences reveal that a large gap exists between the potential value of forecast information and the actual utilization of this information for managing agricultural systems for societal benefits. There is a need for concerted efforts to address these gaps to take full advantage of climate prediction advances.

This paper focuses on issues relating to the evolution of long-lead forecasting over a period of time in the Asia-Pacific monsoon region, recent advances in ENSO prediction and its potential value for managing agricultural systems. While drawing on experiences from the application of long-lead forecasts in recent years, the paper also highlights emerging issues for future action.

The paper draws on information from Australia, India, Indonesia, the Philippines and Vietnam. It is structured into four sections:

1. Evolution of long-lead forecasting in the Asia-Pacific region;
2. Potential value of ENSO-based long-lead forecasts for the agriculture sector;
3. Application experiences of long-lead forecasts during 1997-98 in the Asia-Pacific region; and
4. Emerging issues for future action in the Asia-Pacific region.

1. Evolution of Long-lead Forecasting in the Asia-Pacific Region

1.1 Traditional Forecasts

In many parts of the Asia-Pacific region, agriculture plays a significant role in sustaining livelihood systems of communities. The year-to-year variability of monsoon behavior prompted agrarian communities to search for advance measures to manage risks. They have developed their own methods of climate forecasting based on generations of experience, local religious beliefs and close observations of their environment to anticipate weather patterns (Sukradi, 1998). Communities rely on interpretation of cloud color and form, animal behavior and flowering of certain plants, among others, as indicators of seasonal conditions. Many of these observations have been coded in folk songs and rhymes, and thus passed through generations. While use of these prediction methods varied from community to community, the prevalence of traditional forecasting methods reflects the demand for advance climate information to cope with climate variability in planning for agricultural operations (Eakin, 2000).

1.2 Indian Monsoon

Efforts were made to forecast monsoon behavior one month and beyond on a scientific basis in the late 19th century in India and subsequently in Indonesia. In 1877, India experienced a serious famine caused by highly deficient monsoon rainfall. In response to this, the Government of India called upon H.F. Blanford to prepare monsoon forecasts (Krishna Kumar, 1994). Thus Blanford (1884) was the first to attempt a forecast of the monsoon based on the hypothesis that “varying extent and thickness of the Himalayan snows exercise a great and prolonged influence on the climate conditions and weather of the plains of northwest India”. The success of Blanford’s tentative forecasts during 1882-85 encouraged him to start operational Long-range Forecasts (LRF) of monsoon rainfall covering the whole of India and Burma in 1886. Since then, the LRF of the monsoon has become an important operational task of the India Meteorological Department (IMD). In 1895, Sir John Elliot utilized weather conditions over the whole of India and surrounding regions to prepare an elaborate forecast of the monsoon rainfall. The forecasts after 1895 were based on (i) Himalayan snow cover from October to May, (ii) local peculiarities of pre-monsoon weather in India, and (iii) local peculiarities over the Indian Ocean and Australia (Thapliyal, 1987).

Sir Gilbert Walker (1908) did pioneering work on the Southern Oscillation and published a prediction formula for India monsoon forecasting containing 22 predictors in six forecast formulae differentiated regionally. Walker also succeeded in removing the subjectivity in the earlier forecast methods by involving, for the first time, the concept of correlation in the field of LRF of monsoon rainfall. Subsequent to Walker's work, little progress was made in LRF of monsoon rainfall until the early 1980s.

In 1988, a new forecast model known as "Parametric and Power Regression Model" was developed and put into operational use by the IMD. This model uses 16 regional and global land-ocean-atmospheric parameters, which are physically related with the Indian monsoon. Combining these parameters, a Power Regression Model has been developed to provide quantitative monsoon rainfall forecasts for the whole country. The values of individual parameters that go into the model calculations are based on observations over different periods specific to the individual parameters. Some of these parameters are derived from the Indian area itself, while some are obtained from as far as South America. For a few of the parameters, observations right up to the end of May are required, while others are known during the preceding winter itself.

Thus IMD is in a position to issue the monsoon forecast only by the end of May, i.e., one month before the start of the monsoon season (June-September). Forecasts issued with the help of this technique since 1988 have been found to be fairly accurate. The forecasts and actual performances of monsoons since 1988 are shown in Table 1.

Table 1: Actual and Forecast Monsoon Performance 1988-96
(Rainfall for the Whole Country, % of Long-term Mean)

Year	Actual	Forecast
1988	119	113
1989	101	102
1990	106	101
1991	91	94
1992	93	92
1993	100	103
1994	110	92
1995	100	97
1996	103	96

Source: India Meteorological Department

1.3 Indonesian and Australian Monsoon

The inter-annual variability of rainfall over Indonesia attracted the attention of Dutch meteorologists. As early as 1919, Braak recognized the essential relationship between long-term pressure, wind and rainfall variations in the Indonesian regions. He established that forecasting for the east monsoon rainfall (June-September) was possible with atmospheric pressure as a sole indicator (Jose, 1989).

Of great interest for Indonesian monsoon forecasting was Nicholls' (1981, 1983) direct follow-up of Braak's ideas of more than 60 years earlier, namely to use Darwin pressure in the first half of the calendar year to predict Java rainfall during the second semester. Nicholls (1981, 1983) constructed a linear single-parameter regression model of Djakarta September-November rainfall versus Darwin August pressure during 1951-69 and then used this relationship to predict the rainfall during each of the years 1970-80. The model proved to be capable of explaining 44% of the inter-annual rainfall variance.

Nicholls and Woodcock (1981) and Nicholls (1981) demonstrated that spring (September-November) rainfall in the north Australia region could be predicted some months in advance by successfully verifying earlier work of several pioneers of long-range forecasting. The only predictor used in the studies was monthly mean Darwin surface pressure, observed several months earlier.

Improvements have been made in the seasonal prediction of Indonesian rainfall and the current scheme has been in operation since 1993. This is essentially a statistical-analogue scheme based on a detailed analysis of rainfall data for 102 regions. The seasonal forecasts are based on the following techniques:

1. Statistical (regression) techniques based on relationships between rainfall and SOI;
2. Probability methods based on the time-series of rainfall for that district;
3. Auto-regressive techniques based on the time-series; and
4. General synoptic experience in monitoring the situation current at the time of issuance of the forecast and the seasonal outlook of the Bureau of Meteorology (BOM) of Australia.

Most of the studies on long-range forecasts are primarily based on statistical and empirical techniques. Diagnostic studies of historical datasets over the years have produced several predictors for monsoon rainfall forecasting. These parameters represent different components of the coupled atmosphere-ocean-land system. Although a large number of predictors have been identified so far, uncertainty still prevails in identifying the best set of predictors in view of multi-colinearity, temporal variations of the relationships, and lack of knowledge about the exact physical mechanisms relating to cause and effect. These long-lead forecasts have been used as general alerts for national policy-makers to mobilize resources to manage potential natural hazards.

1.4 El Niño and Southern Oscillation (ENSO) Prediction

The monsoon forecasts of Australia, India and Indonesia considered Southern Oscillation as one of the predictors since the early part of the 20th century. However, the connection between El Niño and Southern Oscillation was appreciated in the late 1960s principally through the work of Jacob Bjerkins. He discovered the tropical coupling between El Niño and Southern Oscillation (ENSO).

The last decade witnessed a major advance in understanding the predictability of the atmosphere from seasonal to inter-annual time-scales (Carson, 1998; NRC, 1996; Palmer and Anderson, 1998). The major impetus in current seasonal to inter-annual time-scale prediction efforts was provided by the Tropical Ocean and Global Atmosphere (TOGA) Program, which was carried between 1985-94. Results from TOGA demonstrated that it is possible to predict sea surface temperatures (SST) related to Pacific Ocean El Niño and Southern Oscillation (ENSO) over time-scales extending from a few months to over one year.

ENSO is one of the known key drivers of inter-annual variability, and has been associated with world-wide extreme climate anomalies, including changes in the space-time patterns of floods, droughts, cyclone and severe storm activity, and cold and hot spells (Cane et al., 1986; NRC, 1996; Ogallo, 1988; Rasmusson and Wallace, 1983; Ropelewski and Halpert, 1989).

The following ENSO patterns have intrinsic value for predicting future climatic conditions.

Annual Phase-Locking: No two El Niño events are ever the same. They differ in intensity and duration. Yet as research continues on the ENSO phenomenon, certain patterns are discernible. One such significant pattern is that El Niño episodes are generally phase-locked to an annual cycle. This means that if an El Niño (or La Niña) becomes established by the middle of a calendar year, it will not alter until sometime early in the following year. As a consequence, most El Niños begin and end between March and June.

This phase-locked pattern is particularly critical for countries like Australia, Indonesia and the Philippines since such patterning has its effects on different seasonal monsoons. The most important period of rainfall occurs during crucial monsoonal months. The intensity of an El Niño episode during these months has a considerable effect on rainfall and cropping systems in virtually all areas of high production and high population (Fox, 2000).

Amplified Climate Variability: One feature of rainfall fluctuations in areas affected by ENSO is the large inter-annual variability. Conrad (1941) examined the dependence of inter-annual rainfall variability on the long-term mean annual rainfall. He found a strong relationship between relative variability (defined as the mean of the absolute deviations of annual rainfalls from the long-term mean, expressed as a percentage of the long-term mean) and the long-term mean precipitation. The relative variability decreased, in general, as the mean precipitation increased. Some of these deviations were due to the influence of ENSO on rainfall. Nicholls (1988) and Nicholls and Wong (1990) confirmed recent data that the ENSO amplifies rainfall variability in the areas it affects, relative to other areas. The amplification factor is substantial in certain areas, which also depend on latitude and mean rainfall.

Biennial Cycle: Phase-locking related to a biennial cycle is a fundamental element of ENSO variability. The biennial mode means the El Niño events will often be preceded and/or followed by La Niña episodes and vice versa. In terms of rainfall, this means that year-to-year changes in rainfall can be extreme. The change from El Niño-related drought to La Niña and wet conditions can be rapid, and usually occurs early in the calendar year (Nicholls, 2000).

Seasonal Variations in Predictability: The SOI has a strong degree of persistence, such that it tends to retain the same value over the following months. Thus once an ENSO event is established, its persistence from one season to another can be used as a tool to predict seasonal rainfall. For example in Indonesia, following the methodology applied to Australia by McBride and Nicholls (1983), maps of lag correlation have been produced between the SOI and Indonesian rainfall in the following season. The greatest simultaneous relationship with SOI is for both June-August and September-November rainfall. For this reason, three-month lag correlation between SOI and these two seasonal rainfalls has been established.

With regard to the June-August rainfall, statistically significant correlations exist over the central part of the country, opening the possibility of predicting June-August rainfall using the average value of the SOI from March to May. On the other hand, insignificant predictive information is found for most stations located over the "non-monsoonal" areas, i.e., the northern part of Sumatra and Kalimantan as well as central Irian Jaya.

Stronger evidence for predictability using the precursor value of SOI is found for the September-November rainfall. This suggests that the low 1997 September-November rainfall experienced by most of these stations could actually have been predicted in advance (Kirono, 1998).

Thus, the ability to forecast some aspects of ENSO signals for time-scales of months to over one year is currently being used to extrapolate potential occurrences of ENSO-related extreme weather and climate events for specific seasons and regions of the world which have strong ENSO signals. Such information now forms crucial components of early warning systems, including the planning, management and operation of agricultural activities in some parts of tropical regions.

2. Potential Value of ENSO-based Long-lead Forecasts for the Agriculture Sector

2.1 Farm Level

Long-range forecasts could provide the indications of monsoon rainfall variability. There are at least four significant aberrations in rainfall behavior that could upset established crop calendars and yields:

1. The commencement of rains may be quite early or considerably delayed.
2. There may be prolonged “breaks” during the cropping season.
3. There may be spatial and/or temporal aberrations.
4. The rains may terminate considerably early or continue for longer periods.

To deal with these aberrations, farmers could respond to forecasts to undertake these measures:

- Change variety for one with shorter or longer duration;
- Change crop species or mix of species, especially combinations of cash and food crops;
- Implement soil and water conservation techniques;
- Increase or decrease area planted, either total, by crop, or by upland or lowland location;
- Adjust timing of land preparation;
- Increase or decrease borrowing for inputs;
- Sell or purchase livestock depending on anticipated cost and availability of feed; or
- Remain in village or migrate to seek off-farm employment or better grazing for livestock.

In Java and the eastern Indonesian region, for example, in El Niño years farmers are frequently misled by initial rains which offer promise but then cease. The false rains tempt farmers to plant. However, as the rain ceases later, the crops usually die during dry spells. Most farmers keep some seed reserves in case they are forced to plant a second time during the wet season. Rarely do farmers have sufficient seed reserves for a third attempt at planting and by the time such a third planting seems necessary, there is little likelihood of success. In most El Niño years, incidences of false rains were noticed. A long-lead forecast could help farmers to wait until the setting in of regular rains (Fox, 2000).

2.2 Provincial Level

Water Resources Management: Water resources managers at catchment, watershed and river basin levels could undertake proactive measures to manage water resources. There is a potential possibility of introducing water budgeting arrangements to prioritize water use and allocate water resources among various competitive users. In areas where water availability for irrigation purposes is scarce, a campaign can be launched to advise farmers to provide minimum irrigation only at the critical crop stages. The lead-time available could be used for augmenting water resources by constructing small-scale water harvesting structures and rehabilitating old irrigation structures.

Compensatory Cropping Program: This has two dimensions. One is to try to compensate for crop loss in the most severely affected areas (MSA) by intensifying the production program and increasing yield in the most favorable areas (MFA) where there are expectations of good rainfall and availability of assured irrigation sources. The second is to make up the crop loss in the same area by taking up short duration cultivars.

Alternate Cropping Strategy: This involves shifting of crops which could be grown on the availability of soil moisture during less than normal conditions. Farmers in Indonesia usually adopt this strategy by replacing paddy crop with maize and other secondary crops. The success of this strategy could depend on government intervention in providing input and market support to farmers.

The above-mentioned approaches need to be matched with irrigation potential and agroclimatic zonation maps to evolve suitable cropping patterns, keeping in view El Niño influences on rainfall patterns in various regions.

Provincial level institutions would have lead-time to provide agricultural input support, credit arrangements and technical advisories to enable farmers to undertake contingency crop plans. Provincial administrations could also provide support for marketing the agricultural products.

2.3 National Level

National level institutions could provide necessary support to provincial administrations and farming communities in terms of resources. National governments can undertake policy decisions to map out potential impact areas and target resources for mitigation measures. They could also undertake policy measures for export and import of agricultural commodities. National governments could undertake measures to plan for food logistics such as procurement of food grains, transport and distribution to potentially affected areas.

2.4 Insights from Crop Models

Climate patterns translate via rainfall variability into associated crop production variability. However, rainfall anomalies are not the only determinant of yield; factors such as starting soil moisture, temperature, planting dates and timeliness of rainfall strongly influence final yields. Crop simulation models capture these effects. As there is potential value in integrating climate forecast information into crop models, certain initiatives have been taken recently to put in place integrated climate crop models in Australia. Based on these experiences, experimental projects are being run in certain sites in developing countries. These two sub-sections capture the potential value of integrated climate crop models in Australia and India.

2.4.1 Australia

Significant physically-based lag relationships exist between an index of ENSO and future rainfall amount and temporal distribution in eastern Australia. Scientists there have shown how phases of the Southern Oscillation Index (SOI) are related to rainfall variability and are useful for rainfall forecasting for many locations in eastern Australia. For large parts of eastern Australia, they have shown that a rapid rise in SOI over a two-month period is related to a high probability of above long-term average rainfall at certain times of the year. Conversely, a consistently negative or rapidly falling SOI pattern is related to a high probability of below average rainfall for many regions in Australia at certain times of the year. As the SOI pattern tends to be phase-locked into the annual cycle (from autumn to autumn), the SOI phase analysis provides skill in assessing future rainfall probabilities for the season ahead.

Wheat crop simulations for various locations in eastern Australia pointed to a consistent median yield reduction in years of negative SOI index during May. However, provided there were adequate soil moisture reserves available at the time of planting, the simulations pointed to high chances of economically viable yields even during El Niño years. Through a detailed on-farm monitoring program, it was established that wheat grown on good soil moisture reserves in 1997 across northeastern Australia performed well, although the seasonal rainfall was substantially below average. The crops were assisted by timely rain at flowering.

The information from rainfall analysis, crop simulation and categorization for seasonal outlooks has been used to examine tactical production decisions relating to wheat, sorghum and chickpeas, and decisions about potential relative benefits from planting wheat or chickpeas in particular years depending on the prevailing climate outlook. Chickpeas have a shorter growing season and a later planting date so they are perceived as a potentially less risky option than wheat when rainfall is scarce.

2.4.2 System for Analysis, Research and Training (START) in Global Change Climate Prediction for Agriculture Program

In September 1997, START established a task group which drafted a strategic plan for the development and implementation of the Program on Climate Prediction and Agriculture (CLIMAG). The CLIMAG strategic plan provides a conceptual framework for the utilization of climate prediction in agriculture. The broad strategy for conducting the project in a specific region would be to:

1. Determine the baseline relationship between climate variability and crop production in the region;

2. Establish awareness in the region of the potential for climate predictions to be used to increase crop yield;
3. Mobilize a multi-disciplinary team to design and execute the project in the region;
4. Identify agriculture practices in the region that may be modified through knowledge of future climate variations;
5. Design a project in which the impact of changes in agriculture practice can be quantified;
6. Conduct a trial with farmers over a number of years where climate information is used to modify agriculture practice as required; and
7. Analyze and disseminate the results of the trial.

Preliminary results of the CLIMAG obtained from two sites in India are given below.

CLIMAG, Tamil Nadu, India: Agricultural production in the Indian state of Tamil Nadu experiences problems due to erratic monsoon seasons, crop failures and improper resource management. Average annual rainfall is 640 mm with most received during two monsoon seasons: the southwest monsoon (172 mm; June-September) and northeast monsoon (321 mm; October-December) in the western part of Tamil Nadu State. For this part of India, the use of SOI phases has shown considerable skill. There is a significant relationship between seasonal rainfall and negative phases of SOI, with a stronger signal during the northeast monsoon. In both seasons, variability is less in negative SOI phases, with chances of getting at least median rainfall considerably higher than in other years. The average dry land crop production in this region is about 0.6 t/ha. The key management decisions are selection of crop, dates of sowing, land management, fertilizer rates, intercultural operations and harvesting. Seasonal climate forecasts could help to increase production by making better-informed management decisions. For instance, preliminary simulation results indicated that if the median August-November rainfall probability is above 400 mm and the soil profile contains at least 50% of stored soil moisture on 15 August, it is advisable to plant cotton. If the condition is not satisfied, it would be better to consider planting sorghum between 15 September and 15 October, provided the median September-December rainfall probability exceeds 300 mm and stored soil moisture is above 30%. Otherwise, millet, sunflower and chickpea could be considered.

CLIMAG, Andhra Pradesh, India: Groundnut is the most important oilseed crop in India with a total production of about 8.2 million ha, of which over 80% is rained. Anantapur is at the heart of the groundnut region of the Indian peninsula, in the state of Andhra Pradesh, which accounts for about one-third of the groundnut production of the country. The district average yield (the district is about 10,000 sq km and the area under groundnut covers about 8,000 sq km) varies considerably from year to year. The yield varies from less than 500 kg/ha to 1.5 tons (which is considered as a crop failure). It has been observed that the variation in yield arises to a large extent from the variation in the total rainfall during the growing season (Gadgil, 2000).

Seasonal rainfall up to 50 cm is required to sustain a successful groundnut crop. When the seasonal rainfall is below this value, there are several years with yield below 700 kg/ha, i.e., low yields from the farmers' fields. On the other hand, when seasonal rainfall is above 50 cm, the probability of yield above 1-5 t/ha is over 50% and that below 700 kg/ha is zero. This suggests the usefulness of a prediction of whether seasonal rainfall will be below 50 cm.

It has been observed that the seasonal rainfall has been less than 50 cm in 21 El Niño years out of 24. This is rather high only with the exceptional El Niño of 1953 during which the all-India monsoon rainfall was also in excess. Thus in 87% of the El Niño years, the seasonal rainfall is below the threshold of 50 cm, which implies a high probability of low levels of yield. Hence, if an El Niño is predicted, it would be worthwhile to minimize investment, for example in chemical fertilizers, or cultivate some other crop such as horse gram. Thus a prediction for El Niño has the potential for application in farm-level decisions. However, it should be noted that of 58 years that are characterized by seasonal rainfall less than 50 cm, only 21 coincide with El Niño. Hence, while prediction of an El Niño will be of considerable use, other predictors for such years have to be explored.

These climate crop models are being tested in a homogeneous environment. They provide information about the potential value of utilizing climate forecast information for managing agriculture systems.

3. Application Experiences of Long-lead Forecasts during 1997-98 in the Asia-Pacific Region

In the previous section, the potential value of climate forecast information was highlighted. A study of actual experiences of forecast information application during the 1997-98 El Niño in Australia, Indonesia, the Philippines and Vietnam are discussed below.

3.1 Australia

The Bureau of Meteorology (BOM) has been preparing season climate outlooks each month for the past decade. They consist of a comprehensive booklet (including tabulations of probabilistic prediction of rainfall in terciles: dry, near normal, wet). It is prepared at the start of the three-month period, after a meeting involving meteorologists, oceanographers and representatives of the agriculture sector (the main user sector for this forecast). From May 1997, BOM has been including indication of a likely El Niño event and hence an increased probability of low rainfall over eastern Australia. The outlook issued in early August indicated: “El Niño persists: Dry weather likely to continue over southeastern Australia”. The summary went on to say that “there is a strong likelihood of significantly drier than normal conditions persisting and expanding across much of eastern and southern Australia”. The tables included in the August outlook indicated that rainfall in the dry tercile was typically two to three times more likely than the wet tercile. In the event, although there were areas where the August-October period was dry, there were also considerable areas with rainfall much above the average (and well into the wet tercile). Moreover, rainfall was good through much of the region in September, a critical time for crops.

A huge communication gap was noted. Part of the problem is attributable to different emphases placed by forecasters and users on certain critical words. It appears that users and forecasters interpret “likely” in different ways. Those involved in preparing the forecasts and media releases intended this to indicate that dry conditions were more probable than wet conditions, but that there was still some chance that wet conditions would occur. Many users, it appears, interpreted “likely” as “almost certainly dry, and even if it wasn’t dry then it would certainly not be wet”.

Lack of knowledge about interpreting and using ENSO forecasts caused many farmers to have inappropriate expectations of El Niño and to take inappropriate actions to cope with it. As a result, the forecasts in some cases probably did more harm than good. It was reported that some farmers overreacted, selling large portions of their herds and not planting a crop.

3.2 Indonesia

Prior to 1997, the Bureau of Meteorology and Geophysics (BMG) generally used to issue weather forecasts keeping in view meteorological parameters. From 1997 onwards, the BMG has taken the initiative to establish a broad-based National Seasonal Forecasting Working Group drawing upon expertise from various sectors. This Working Group comprises BMG, the Bureau of Assessment and Application of Technology (BPPT), the National Space Center (LAPAN), the Agriculture Research Institute and the Water Resources Management Research Institute.

The Working Group draws upon forecast information from the ASEAN Specialized Meteorological Centre (ASMC), IRI, BOM Australia and the UK Metro Office to prepare seasonal forecast guidance for 102 meteorological regions across the entire country, including:

1. Seasonal monsoon onset forecast indicating the dates of monsoon onset at ten-day intervals;
2. Monthly forecast of rainfall; and
3. Seasonal cumulative rainfall status for the entire season.

Respective climate-sensitive organizations at the national level, on receipt of climate forecast information from BMG, process the outlook with reference to past impacts and disseminate processed information to provincial sectoral organizations. At present, these forecasts are used as a general alert. The information is received from the field agencies by the national level user agencies only when disaster events occur. The processed forecast information received at the national level is useful for taking general precautionary measures but cannot be used for comprehensive development planning.

During 1997-98, the Department of Agriculture, on receipt of the information from BMG on the likely impact of El Niño, processed the information and disseminated it to provincial agencies in a routine way (Table 2).

It may be seen that it took about six weeks for the forecast information to reach farmers with some general recommendations. They did not benefit from the forecast information as they planted on schedule with the first rains in September-October. The rains ceased thereafter. Farmers had to replant again and again. As a result, around 900,000 ha of crop area was reported to be affected by drought to varying degrees.

Table 2: Timeline for Processing and Disseminating BMG Forecast

Day 0	Press release of the seasonal forecast by BMG
Days 7-10	Official receipt of BMG forecast by Ministry of Agriculture
Days 10-15	Ministry of Agriculture forwards to provincial agriculture extension services, indicating the potential impacts and the broad contingency measures to be taken
Days 23-30	Receipt of communication by provincial agriculture services
	Meeting of climate working team for deliberations about the impending drought at provincial level
Days 30-40	Dissemination of information by provincial government to districts and sub-districts with general recommendations about the need for taking possible action

As no concerted efforts were made to take the lead-time provided by the ENSO forecast, a loss of around three million tons of rice was reported. The Government had to import five million tons of food grain to ensure food security in the country.

3.3 Philippines

PAGASA, the Philippine meteorological agency, incorporates ENSO indices as one of the major parameters in its long-range forecast scheme. PAGASA provided early warning about the 1997-98 El Niño in 1996 itself and the first drought advisory was issued in May 1997. The advisories indicate the broad weather outlook. An extract of the seasonal climate forecast issued by PAGASA in May 1997 reads:

> *Based on these recent evolutions and forecast of the atmospheric and oceanic conditions, it can be expected that warm episodes will intensify during the next several months. This climate forecast of an impending warm episode will have global scale implications. For the Philippines, some climate tendencies during the seasons are indicated below.*

> Southwest Monsoon Season (May-September 1997): *In view of this new development, the onset of the rainy season (which normally occurs during the second half of May) is expected to be delayed by about two weeks. With this, the duration of rainy season, which normally ends during the early half of October, may be short-ended, although some bursts of heavy rainfall during the rainy season could also be expected, mostly in the western section of Luzon and some parts of western Visayas.*
>
> Northeast Monsoon Season (October 1997 to March 1998): *The impending warm episode in the central and eastern equatorial Pacific will have an influence on the activity of tropical cyclones in the PAR. Below normal tropical cyclone activity will most likely occur during the coming northeast monsoon months. This will cause below normal rainfall conditions in a bigger portion of the country.*

An extract of the drought advisory issued by PAGASA before the commencement of the northeast monsoon of 1997-98:

> *Based on trends, climatological studies and the present atmospheric and oceanographic situation in the central and eastern equatorial Pacific, manifestations of the effects of the existing El Niño phenomenon on the Philippines climate will have its peak during the northeast monsoon season (October-March). Atmospheric sea level pressure in the eastern equatorial Pacific including the Philippines will be above the normal while sea surface temperature will be below the normal. Consequently, below normal tropical cyclone activity is expected in the PAR. With these factors, drier than normal weather conditions can be experienced in the Philippines starting in October 1997 and continuing through March 1998.*

Expressions such as “drier than normal weather conditions” and “bigger portion of the Philippines would experience moderate to severe drought” have been interpreted by the user departments as meaning that the whole of the Philippines would be affected by devastating drought. An El Niño task force was constituted at the national, provincial and other levels throughout the Philippines. Resources were distributed to all the regions of the country.

The drought impact was confined to certain areas only. Farmers did not get the location-specific advisories to change crops. Thus, around 600,000 ha of corn and rice land were affected by drought. Around 1.2 million tons of food grain production was reported.

Although establishment of a comprehensive climate forecasting applications system is well under way in the Philippines, there is still a great need to develop capabilities to process forecast information into more actionable formats at the local level. The information provided by the national agencies falls short of meeting the specific needs of users at local levels.

3.4 Vietnam

The Hydro Meteorological Services (HMS) uses antecedent parameters such as Eurasian snow cover and ITCZ for making seasonal forecasts. In recent months, after the initiation of the Extreme Climate Events (ECE) Program, HMS has begun to incorporate ENSO into long-range forecast information and seasonal forecasts.

The seasonal forecast information provided by HMS is used by climate-sensitive sector agencies like agriculture, water resources and disaster management only as a general alert. A lot of progress needs to be made to make full use of climate forecast information for development planning.

3.5 Fiji

The primary agency for meteorological monitoring, forecasting and research in Fiji is the Fiji Meteorological Service (FMS). This organization has strong professional linkages with equivalent groups in New Zealand, Australia and the Pacific ENSO Application Center in Hawaii. Forecasting is done using (1) general monthly rainfall pattern analysis, (2) analysis of past ENSO warm and cold events, (3) rain forecast models (both locally and foreign developed), and (4) regional prediction models from foreign agencies (Kaloumaira, 2001).

No local specific action was undertaken during 1997-98 to minimize losses of sugarcane, the primary agriculture industry in Fiji, with reports of 50% sugarcane production loss affecting 200,000 farmers.

4. Emerging Issues for Future Action in the Asia-Pacific Region

The discussion in Section 2 indicated that skill in climate prediction offers considerable opportunities for managers to reap benefits (e.g., increased food production and profit and/or reduced risks). Section 3, however, reveals that realizing these opportunities is not straightforward since the forecasting skill is imperfect and approaches to applying the existing skill to management issues have not been developed and tested extensively. While much has been written about impacts of climate variability, there has been relatively little done in relation to applying knowledge of inherently imprecise climate predictions to modify actions ahead of likely impacts, i.e., applications of climate prediction. An effective application of a seasonal climate forecast is defined as use of forecast information leading to a change in a decision that generates improved outcomes in the system of interest.

Considerable efforts in various parts of the world are now being focused on the issue of applying climate predictions to improve agricultural systems. This section will discuss emerging issues in applying long-range forecast information in the Asia-Pacific region, drawing lessons from the experiences of applying forecast information during the 1997-98 El Niño and 1998-99 La Niña. These are:

1. Delimitation of ENSO-sensitive sectors, seasons and regions;
2. Utilization of climate forecast with coarse resolution;
3. Articulation of users' needs;
4. Integration of intra-seasonal oscillations; and
5. A systems approach to climate forecast and application.

4.1 Delimitation of ENSO-sensitive Sectors, Seasons and Regions

The climate exhibits only limited predictability and skillful forecasts are available for some seasons and regions. While in some areas there are clear relationships between ENSO indices and local climate variables, other areas do not exhibit a linear relationship. It would take some time to obtain climate forecasts with greater geographic resolution covering all factors governing climate variability.

It is therefore necessary to delimit specific climate-sensitive zones which are relatively highly sensitive to ENSO indices, and where a specific relationship exists between ENSO indices and local climate variability when compared to other areas. After spatial delimitation of the geographic zones, a temporal delimitation of comparatively more ENSO-sensitive seasons than other time periods needs to be undertaken. For instance, summer season is more sensitive to ENSO than the dry season, which is by and large protected by assured irrigation systems. Delimitation of climate-sensitive zones, sectors and seasons would facilitate application of forecast information at local levels.

The documentation of past ENSO events could provide insights for mapping specific areas likely to be affected by future El Niños. The Extreme Climate Events (ECE) Program implemented by the Asian Disaster Preparedness Center (ADPC) in Indonesia, the Philippines and Vietnam, is primarily to document the impacts of past extreme climate events and map out ENSO-sensitive regions in these countries. This approach assisted the countries to prepare general vulnerability maps to manage future ENSO events.

4.2 Utilization of Climate Forecast with Coarse Resolution

A commonly recognized problem in the application of climate forecasts in the agricultural community is that currently available seasonal forecasts are at too large a scale to be useful for site-level planning. Both spatial and temporal scales need to be refined for agricultural management applications. There is a need to downscale the global ENSO index-based forecast into local level climate outlook products. These need to be further downscaled, keeping in view specific vulnerabilities at the local level with reference to different seasons and cropping systems. Intermediary research organizations in the countries could be assisted to translate the coarse ENSO forecast information into an actionable format for specific uses at the end-user level.

4.3 Articulation of Users' Needs

Most research has been driven from the climate and agro-ecological communities, and has tended to involve a top-down approach, where uses are sought for existing forecast information, and less commonly by a bottom-up approach, where a decision situation is examined to identify niches and needs for climate forecasts. Also, most current forecast products lack the spatial, temporal and element specificity that users seek for their specific decision-making needs.

Users are diverse and cannot be lumped into a homogeneous set. Even within the agricultural sector, the needs of agribusinesses such as seed suppliers and grain traders vary distinctly from primary producers. Among producers, limitations in access to resources or risk exposure condition responses to new information. One characteristic of users is self-sufficiency or survival (subsistence producers) or profit maximization (commercial). This plays a critical role in what information they would be willing to use.

Even if a locally-actionable climate forecast is available, the communication of probabilistic forecast information could be problematic for end-users. There is a need to develop a communication package that keeps in view socio-cultural peculiarities of communities whom the forecasts are intended to benefit.

Even if a locally-actionable climate forecast is available and communication is also perfect, there could be other constraints for farmers to respond to the forecast, such as:

- Lack of credit access or previous debt burden;
- Competing demands for labor;
- Limited access to ploughs, seed of suitable varieties and other inputs;
- Limited land access;
- Untimely dissemination of forecasts (farmers need them by the end of April at the latest);
- Priorities and strategies for risk aversion and risk management;
- Market access or stability of prices and demand for cash crops;
- Decision irreversibility;
- Inappropriate forecast information;
- Lack of confidence in forecast or in the source or provider of the information;
- Diversity and level of income, both on-and off-farm; and
- Local consumption preferences for crop varieties.

There is a need to evolve national level policies and programs to address these constraints so that farmers can use climate forecast information.

4.4 Integration of Intra-seasonal Oscillations

A long-range forecast would provide an indication of the behavior of rainfall during the course of a season. However, there could be meso-scale intra-seasonal oscillations which may result in long dry or wet spells, cyclones and storms. Farmers will encounter these disturbances in the course of the cropping season, during which certain mid-term corrections will be required to minimize crop yield losses. Hence, a short-term forecast of 5-10 days will provide critical information for undertaking corrective measures.

A long-range forecast system coupled with monitoring of seasons and weather behavior would be necessary for taking into account intra-seasonal variabilities.

4.5 A Systems Approach to Climate Forecast and Application

The application of climate prediction information requires close consideration of the roles of and interactions among the full span of climatic, ecological and social factors involved. This includes climate observation systems, the choice of climate prediction tools, the design of climate forecast products to suit users' needs, communication of the forecast products, sector system models (crop climate models), decision behavior, institutional constraints and social settings in which the decisions are made. A continuous dialogue mechanism between climate information producers, intermediary research organizations, and policy-makers and end-users needs to be institutionalized.

ADPC promoted establishment of climate information and user networks in Indonesia, the Philippines and Vietnam. These institutional arrangements would view climate variability as a continuous phenomenon. They would meet before the onset of wet and dry seasons to utilize the forecast for mapping out potential impacts and undertaking measures to manage the likely impacts. This co-learning process would facilitate better appreciation of climate variability, limitations of forecast skills and constraints and opportunities for utilization of climate forecasts.

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