Economic and Social Commission for Asia and the Pacific

CGPRT Centre Monograph No. 43

Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific

Proceedings of a Joint Workshop
Held in Cebu, the Philippines
September 17-19, 2002

United Nations

The CGPRT Centre

The Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT Centre) was established in 1981 as a subsidiary body of UN/ESCAP.

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In co-operation with ESCAP member countries, the Centre will initiate and promote research, training and dissemination of information on socio-economic and related aspects of CGPRT crops in Asia and the Pacific. In its activities, the Centre aims to serve the needs of institutions concerned with planning, research, extension and development in relation to CGPRT crop production, marketing and use.

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Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific

"CGPRT Centre Works Towards Reducing Poverty Through Enhancing Sustainable Agriculture in Asia and the Pacific Region"

CGPRT NO. 43

Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific

Proceedings of a Joint Workshop Held in Cebu, the Philippines September 17-19, 2002

Edited by
Shigeki Yokoyama
Rogelio N. Concepcion

CGPRT Centre
Regional Co-ordination Centre for
Research and Development of Coarse Grains,
Pulses, Roots and Tuber Crops in the
Humid Tropics of Asia and the Pacific

JIRCAS
Japan International Research
Center for Agricultural Sciences

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Foreword

An international joint workshop on “Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific” was held during September 17-19, 2002 in Cebu, the Philippines. This event was originally planned as a regional workshop to discuss and disseminate major findings achieved in a three-year research project “Stabilization of Upland Agriculture and Rural Development in El Nino Vulnerable Countries (ELNINO).” In the course of implementing the project, we learned that several international and national institutes have been approaching the common issue, agricultural climate risk, from various points of view and ways. Through close communications with them, we recognized that we could benefit each other and agreed to organize a joint workshop to exchange our findings and to establish synergy for further collaboration.

It is my great pleasure to publish **“Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific: Proceedings of a Joint Workshop Held in Cebu, the Philippines, September 17-19, 2002.”** I thank all the participants of the workshop who contributed to enhance our knowledge base through paper presentation and active discussion. I also thank Mr. Shigeki Yokoyama and Dr. Rogelio N. Concepcion for their efforts in compiling and editing this volume. I would like to express my sincere gratitude to Department of Agriculture, the Philippines, Japan International Research Center of Agricultural Sciences (JIRCAS), Australian Centre for International Agricultural Research (ACIAR), and International Water Management Institute (IWMI) for their support as co-organizers of the workshop.

I believe this volume will provide a wide range of information and insights regarding agricultural climatic risk in Asia and the Pacific to the readers.

Nobuyoshi Maeno
Director
CGPRT Centre

Foreword

Global climate change poses a great threat to world food security and sustainable development. It is necessary to deal with the problem through the mutual cooperation of countries around the world. Extreme climate episodes caused by El Nino are one of the most serious problems in Asia and the Pacific region. Japan International Research Centre for Agricultural Sciences (JIRCAS) promotes research aimed at achieving a stable global food supply and ensuring sustainable development of agriculture, forestry and fisheries in harmony with the environment. It carries out interdisciplinary research on biological and social aspects of agriculture, forestry and fisheries, and undertakes collaborative projects with institutions of developing countries as well as international organizations.

Technological development of crop production under unfavorable climate conditions is one of the key issues of JIRCAS's activities. Therefore, it is significant that an international joint workshop on "Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific" was held and that JIRCAS had the honor of becoming one of the co-organizers of the workshop along with such esteemed institutions as the CGPRT Centre, the Department of Agriculture, the Philippines, the Australian Centre for International Agricultural Research (ACIAR), and the International Water Management Institute (IWMI). As indicated in these proceedings, prominent scientists discussed the results of state-of-the-art research related to climate change and disaster mitigation systems, and delivered their country's reports concerning the impact of El Nino and coping mechanisms in Asia and the Pacific region. I hope these proceedings will provide a comprehensive understanding of the current knowledge about El Nino-induced climate change and disaster mitigation techniques.

Finally, I thank Dr. Nobuyoshi Maeno, Director of the CGPRT Centre, for providing us the opportunity to organize this workshop. My appreciation is also extended to all the other co-organizers and participants who attended the workshop.

Takahiro Inoue
President
JIRCAS

Acknowledgements

We would like to express our sincere gratitude to the authors of the keynote presentations, country reports of ELNINO project, and commentators on country reports. It is appreciated that we benefited from useful comments and suggestions from all the participants during the workshop.

Special thanks are due to Ms. Salve Cas and other support staff of the Bureau of Soil and Water Management, the Philippines. They provided excellent logistic and management work in the course of preparation and during of the workshop. Without their strenuous efforts, we could not have completed the event successfully.

Our acknowledgments are extended to Dr. Nobuyoshi Maeno and Dr. Haruo Inagaki, current and former Director of the CGPRT Centre, for his continuous support of our activities. Last but not least, we wish to express our thanks to the support staff of CGPRT Centre, Mr. Matthew L. Burrows for English editing, Ms. Francisca Wijaya for secretarial assistance, Mr. Muhamad Arif for graphical editing, and Ms. Agustina Mardyanti for typing.

Shigeki Yokoyama
Leader, ELNINO project

Rogelio N. Concepcion
Regional advisor, ELNINO project

Opening Message

Leonard Q. Montemayor[*]

(Read by Ernesto M. Ordonez, Director, Department of Agriculture-Region 7)

I warmly welcome the delegates, participants and guests to this workshop on coping with El Nino and stabilizing rainfed agriculture. Indeed, rainfed agriculture, with its diversity and unpredictability, is a challenging issue. Due to various limitations, we cannot bring the benefits of irrigation to these rainfed areas. Mostly grown to rice and corn, they are most vulnerable to climactic risks. Certainly the onslaught of El Nino presents a major concern. It is therefore commendable that a workshop like this is organized at the regional level. Allow me to congratulate the sponsors and organizers of this workshop.

Water is the most essential resource for all vital processes of mankind. Yet, while seventy per cent of the earth's surface is covered by water, it is ironic that about two billion people live in areas with chronic water shortages. Such a lack of water poses a serious constraint to the development of the economy and of the people living in these areas. I therefore welcome your efforts to prioritize a wide range of relevant issues including, land degradation and watershed management, El Nino reports from other countries and local capacity building to mitigate the effects of drought.

We all understand that vulnerability to climatic changes and famine is a complex web of cause and effect that spans the whole environmental, social, economic, and political spectrum. The groups most vulnerable to climatic risk are those most easily affected by changes in commodity prices and with least capacity to cope with unfavorable changes in agricultural conditions and access to food. They suffer the severest consequences of famine and malnutrition. The World Food Summit convened in 1996, highlighted the basic right of all people to adequate food and nutrition and the need for concerted action among all countries to achieve global food security in a sustainable manner. The Philippine government subscribes to this goal.

So allow me at this point, to share with you the major programs of the Department of Agriculture aimed at helping farmers cope with El Nino and optimize rainfed agriculture towards increased productivity. Food security and poverty alleviation are the top priorities of the Macapagal Administration. To achieve these goals, we are now implementing the Agriculture and Fisheries Modernization Act, otherwise known as AFMA. Aimed at strengthening the agricultural and fishery sectors through modernization, AFMA is guided by the principle of food security and food self-sufficiency, global competitiveness and private sector participation, social equity and poverty alleviation and resource sustainability and people empowerment.

The Ginintuang Masaganang Ani Program or GMA is the banner productivity program for putting AFMA to work. It strengthens the leadership of the local government units and at the same time, addresses poverty alleviation by providing full support to marginal areas, most of which are rainfed. Basically, GMA programs promote the diversification of agricultural opportunities in resource poor, non-irrigated areas including the development of high value crops with the ultimate objective of providing our farmers in rainfed and upland areas alternative production options.

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[*] Secretary, Department of Agriculture, the Philippines.

The program addresses the need to effectively respond to climatic risk brought about by El Nino and prolonged dry spells, especially in marginal and rainfed areas. The Bureau of Soils and Water Management (BSWM) speeds up the establishment of small water impounding projects and diversion dams wherever feasible, not only as a soil and water conservation strategy but also as support to rice production areas that national communal irrigation systems cannot service. Supplemental water is also provided by shallow tube wells. There are on-going research efforts to improve the efficiency of on-farm water use and management. We conduct cloud-seeding sorties whenever necessary. The “balanced fertilization strategy” which uses a mix of site-specific organic and in-organic fertilizers is being promoted in major rice and corn areas to improve and maintain the fertility of agricultural lands.

In closing, allow me to share with you some policy advocacies which this workshop can consider as we address the risks of El Nino and enhance rainfed agriculture in Asia and the Pacific. Firstly, I think we have conducted and shared with each other enough research on water conservation. It is now time to commercialize these technologies and make them available to farmer beneficiaries at a reasonable cost. Secondly, focusing on rainfed soil and water management, this workshop is providing us, especially the various research institutions, a venue for networking and collaboration. I certainly encourage more activities of this type.

I wish to emphasize that the goals you have set in this workshop cannot be achieved by yourselves alone. To succeed in your endeavors, you will need the active participation of all the stakeholders and advocates of sustainable and equitable agricultural development. I therefore urge everyone to actively participate in shaping an effective regional strategy for coping with and preventing El Nino as well as enhancing food productivity in marginal and rainfed areas. I wish you a productive and successful workshop.

Thank you and good day to all of you.

Opening Address

Sang Mu Lee[*]

(Read by Arcadio Cruz, FAO, program officer)

Honorable Ernesto M. Ordoñez, Undersecretary of the Department of Agriculture, Honorable Pablo P. Garcia, Governor of Cebu, Mr. Shigeki Yokoyama, El Nino Project Leader, CGPRT, Mr. Eiji Ueno, First Secretary, Embassy of Japan, Dr. Rogelio Conception, Director, BSWM, Distinguished Guests, Participants, Ladies and Gentlemen:

On behalf of the Food and Agriculture Organization of the United Nations, I would like to convey its compliments, support and encouragement for this workshop on Coping against El Nino for Stabilizing Rainfed Agriculture in Asia and the Pacific. Please allow me also to express my personal appreciation to the organizers, for their foresight and pragmatic approach in tackling the possible scenarios expected to be brought about by "El Nino".

I will not touch on the technical aspects of El Nino, as these will be discussed thoroughly in this Workshop. Instead, I will focus on FAO's overall strategy in mitigating the impact of El Nino, issues and open questions relating to the causes and to the potential impacts of climate change in general. I will also try to discuss various actions which are currently undertaken by affected countries or countries expecting to be affected with support from FAO. I will include past, present and future actions that FAO does and/or promotes and which are all geared towards food security and better management of agricultural emergencies.

Disaster management

The challenges facing agriculture and of assuring global food security and the sustainable management of natural resources are manifold and immensely complex. Agriculture is intimately tied to nature and hence subject to its vagaries. How nature is harnessed through agriculture, however, has become a source of intense controversy, and the sustainability of the technologies on which the intensification of farming is based is being increasingly questioned. Debate is also intensifying over the interactions between agriculture and the processes of climate change which are not only significantly affected by how land is used but are also expected to have increasingly disturbing impacts on agriculture.

Natural and man-made disasters are a major source of human casualties, injury and displacement, they also have tremendously damaging effects on farmers' welfare as well as their assets, and on local and national food supplies. If not properly managed, such disasters can induce serious food shortages, create conditions in which famine can take its toll on affected populations and disturb global food markets. Although much has been learnt from experience on how to predict most types of disasters and new technologies are raising the lead time for the issuance of warnings of adverse weather events, there has been an alarming increase in the number of countries per year affected by disasters since the WFS.

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[*] FAO representative.

FAO's role in mitigating the impact of El Nino

FAO continues to be actively involved in helping countries prepare for and respond to the adverse impacts of El Nino. In a number of countries, the Organization has increased awareness among Governments of weather hazards to allow more location specific impact scenarios to be developed. It has also strengthened ongoing development activities that have an additional preventive relevance in light of current and future weather anomalies and El Nino. Examples of measures promoted by FAO include:

- Support to well construction and small-scale irrigation development programmes in southern Africa and central America;
- Development of drought and cyclone-resistant cropping patterns and farming and fishing practices for South Asia, the Sahel, eastern and southern Africa and the Caribbean;
- Support for the preparation of a disaster preparedness strategy for member countries of the Intergovernmental Authority on Development in eastern Africa;
- Provision of information and direct assistance to member countries on appropriate forestry policy and planning, forest management and land use decision making, environmentally sound logging, fire control, etc.;
- Support to flood prevention through integrated watershed development programmes in eroded, mountainous regions and support for the design and management of strategic food security reserves.

Specific country, regional and global level activities of FAO include the following:

i. Crop and food supply monitoring

Since the onset of the current El Nino, FAO through its Global Information and Early Warning System (GIEWS), has intensified the monitoring of weather developments and crop prospects in all parts of the world. The System has issued several special reports on the impact of El Nino on crop production in Latin America, Asia and Africa. FAO/WFP Crop and Food Supply Assessment Missions were fielded to Indonesia, Angola, Mozambique, Zambia, DRP Korea and Tanzania, where crop losses were caused by weather anomalies.

ii. Emergency agricultural rehabilitation

Since the onset of El Nino induced disasters, FAO's Special Relief Operations Service (TCOR) has fielded a number of missions to countries affected by serious weather anomalies in central America, eastern Africa, Asia and the Pacific Rim, to assess needs for essential agricultural inputs to restore production as well as immediate rehabilitation and preparedness interventions.

iii. Impact on livestock

El Nino-related drought has had a considerable impact in Asia, especially in Indonesia and the Philippines, which may trigger above normal livestock slaughter, with depressing effects on prices. Reduced output of feed grains due to drought, coupled with severe foreign exchange constraints, might also result in a downsizing of the intensive poultry and pig industries.

iv. Impact on forests and natural vegetation

One of the greatest El Nino-related threats to forests and natural vegetation is the increased risk of wildfires, due to drought conditions. Drought raises the flammability of vegetation and creates other conditions for the spread of fires, leading to an increased number of fires, area burned and intensity of burning.

Forest fires in critical watershed areas may have a significant affect upon agricultural production on lands downstream. Given the link between forests and food security, the increased risk of wildfires and resulting forest damage associated with El Nino has a potential impact upon national and household food security.

v. Impact on fisheries

The area off western South America is one of the major upwelling regions of the globe, producing 12 to 20 percent of world's total fish landings. This is one of the areas that has been most severely affected by the 1997-98 El Nino. Raising coastal sea temperatures and weakening the upwelling process has caused a severe decline in biomass and total production of small pelagic shoals, which are otherwise readily available in the area, particularly off Ecuador, Peru and Chile. This has caused and is still causing large loses to the fisheries sector in the area, as well as a worldwide shortage of fishmeal and fish oil.

Other negative effects of El Nino have also been reported for other regions of the world, and of particular relevance is the unprecedented coral reef bleaching in the Indian Ocean and the tropical eastern and western Pacific. This has obvious fishery and environmental impacts for the areas concerned.

FAO continues to monitor the situation on a regional and global basis, and has been in contact with the CPPS (the "Comision Permanente del Pacifico Sur", a regional body covering the SE Pacific, the area most severely hit by El Nino).

Conclusion

FAO does not have any mandate in the geo-physical aspects of the El Nino phenomenon. Its interests are only in the impacts on agriculture and consequently food security – of the extreme negative/positive climatic events that can be triggered by El Nino. This involves essentially, the monitoring of the ENSO situation, which is now easily done through a number of excellent World Wide Web sites, for instance, the International Research Institute for Climate Prediction (http://irl.ucsd.edu), the Climate Diagnostic Centre (http://www.cdc.noaa.gov), the American Geophysical Union (http://earth.agu.org), the Institut Francais de Recherche Scientifique poul le Dévelopment en Coopération (http://www.orstom.fr), as well as the other WWW sites.

The proper reaction to extreme ENSO events must be seen in a broader context, i.e. the development of a strategy covering extreme atmospheric factors in general and involving several institutional partners. Current discussions about how to react to El Nino are useful only if they lead to long-term solutions. It is suggested that a proper strategy would incorporate the following:

- National Meteorological Services should improve their capability to issue sub-national seasonal forecasts for their main agricultural areas, including realistic and reliable probabilities of occurrence.
- Agricultural services should develop decision/simulation tools incorporating, next to "future climate" economic considerations as well.
- National Agricultural Research Institutes should look into the mechanisms linking ENSO and agricultural impacts.
- Climate/weather impact on agriculture should be seen as much in terms of opportunities and more efficient use of climate resources by farmers rather than only in terms of loss mitigation.

As El Nino develops, some of the expected consequences actually materialize, while others are not verified. It is clear that the current event is exceptional in terms of the attention it received from the media, governments and the man on the street alike. Some countries were able to realistically manage the situation while others over-reacted or found themselves completely unprepared. Much can be learnt from the current situation in terms of adaptation and mitigation strategies.

Finally, I wish you fruitful deliberations that will allow this Workshop to tackle a number of difficult issues and help shape a national and regional climatic change preparedness policy. I have no doubt that your deliberations will form the basis for effective and well coordinated activities to mitigate the possible effects of El Nino and reduce the obstacles to the attainment of reduced hunger and poverty in Asia and the Pacific.

I wish you all the best. Thank you and Good Day!

Opening Address

Eiji Ueno[*]

Hon. Pablo P. Garcia, Governor, Cebu Province, Hon. Ernesto M. Ordonez, Undersecretary, Department of Agriculture, Philippines, Dr. Sang Mu Lee, Resident Representative, FAO, Dr. Nobuyoshi Maeno, Director, CGPRT Center, Distinguished Guests, Ladies and Gentlemen:

Good Morning to you all,

It is a distinct honor for me to attend this Joint Workshop for "Coping against El Nino for Stabilizing Rainfed Agriculture" today here in Cebu. On behalf of the Japanese Government, I firstly would like to express my gratitude for the cooperation exerted by the ESCAP and the countries involved in this project. Also, special thanks to the Philippine Government and the Province of Cebu, for the excellent hosting of this workshop.

I still remember my visit two and half years ago to General Santos in Southern Mindanao, one of the most affected areas by the 1997-1998 El Nino. I joined a turnover ceremony of agricultural commodities to the area, granted by the Government of Japan. I was impressed with the great appreciation by farmers there, which also made me realize how badly affected the area had been. For the calamity brought by the 1997/98 El Nino, the Government of Japan also provided other countries like Indonesia with emergency assistance. Again, the cycle of the El Nino phenomenon seems to have become shorter recently and therefore, we have to prepare for the expected El Nino this year.

Japan believes that food security in Asia and the Pacific countries can be achieved with continuous efforts for stable production. In this regard, this El Nino project is contributing greatly, under the participation of many countries and international organizations. The Government of Japan funded ESCAP, then the CGPRT Centre implemented the project with five countries, namely Indonesia, Malaysia, Papua New Guinea, the Philippines and Thailand.

We expect that this project will serve as a good implication for policy making in the member countries, by finding socio-economic impacts of El Nino and exploring effectiveness and constraints of countermeasures carried out by farmers, local and central governments.

Again, I would like thank you very much for the cooperation of each country and international organizations, and hope you have a beneficial discussion today.

Thank you very much and have a good day.

[*] First Secretary (Agriculture), Japanese Embassy, Manila, the Philippines.

Opening Address

Takahiro Inoue[*]

(Read by Tomohide Sugino, Research Planning and Coordination Division, JIRCAS).

Distinguished Guests, Participants, Ladies and Gentlemen:

On behalf of the Japan International Research Center for Agricultural Sciences (JIRCAS), one of the co-organizers of the Workshop, I would like to extend my cordial welcome to all the participants in the Joint Workshop: Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific.

The organization of such a Workshop is particularly timely and underscores the importance of establishing countermeasures to promote sustainable agriculture under abnormal weather caused by El Nino. The last El Nino event occurred in 1997, intense rainfall, floods, drought and forest fires caused great damage to Asia and the Pacific region, to the tune of approximately 100 billion dollars. El Nino effects most seriously, the tropical region near the equator but abnormal weather occurs also in mid and high latitude areas of Asia, North and South America, and even Europe. We should fully recognize El Nino as an urgent and crucial concern to achieve sustainable development in the World.

As you may know, JIRCAS (formerly Tropical Agriculture Research Center (TARC) until 1993) is implementing research collaboration programs in the field of agriculture, forestry and fisheries with a large number of institutions in developing countries located in the tropics, subtropics and temperate zones, in addition to conducting advanced studies at JIRCAS Headquarters in Tsukuba and at the Okinawa Subtropical Station.

On April 1, 2001, JIRCAS became an Independent Administrative Institution (a semi-autonomous agency) under the supervision of the Ministry of Agriculture, Forestry and Fisheries (MAFF). The mandate given to JIRCAS by the Japanese Government does not change fundamentally. The most distinctive feature of the new Independent Administrative Institution is the semi-autonomy with limited prior control from outside and the *ex post facto* evaluation. In the new system, JIRCAS drafts a Mid-Term Plan to achieve Mid-Term Objectives, which are defined by MAFF.

We have always been aware of the importance of developing technology for the improvement of production under unfavorable climate conditions. As a result, in the JIRCAS Mid-Term Plan, we focus on the research theme "Analysis of meteorological factors responsible for the instability of crop production on tropical and subtropical islands and the development of technology for crop cultivation using low water input". We are carrying out research activities concerning the technology to mitigate climate disasters, such as trench cultivation systems and underground drop irrigation at the Okinawa Subtropical Station. We are also developing the predictive model for world food demand and supply on a long-term basis to forecast the effects of environmental change at the Development Research Division, JIRCAS Headquarters in Tsukuba.

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[*] President, Japan International Research Center for Agricultural Sciences (JIRCAS).

The organization of this Workshop, with the participation of a large number of researchers from various countries located in Asia and the Pacific Region certainly emphasizes the importance of international collaboration for the improvement of production under the El Nino induced unfavorable climate conditions.

I am convinced that valuable exchanges of information will take place during the Workshop.

I again wish to extend my cordial welcome to all the guests and participants.

Thank you.

Opening Address

Nobuyoshi Maeno[*]

Dear participants;

Good morning and welcome to Cebu;

First of all, on behalf of the CGPRT Centre, I would like to express my sincere appreciation for your participation in this joint workshop.

The CGPRT Centre, as one of the subsidiary bodies of the UN ESCAP, has been implementing various activities to contribute to alleviating poverty through promoting the sustainable development of agriculture, based on CGPRT crops in Asia and the Pacific region.

CGPRT crops are a very important component of the farming system in the region, particularly in the marginal areas where economically, ecologically and socially less favorable conditions prevail, and many farmers' activities and lives rely on CGPRT crops. Therefore, it is crucial to promote the sustainable production of CGPRT crops.

The El Nino-induced abnormal weather, tends to be increasing in its frequency of occurrence, magnitude, duration and irregularity in recent years. According to the press, the abnormal weather is returning this year, like the very heavy rainfall and flooding in Europe, Russia and China and on the other hand the drought in some regions of China and South Asia.

Accordingly, it is urgent for rainfed upland agriculture, where most CGPRT crops are grown, to establish technological and institutional countermeasures to predict, avoid or minimize and recover from the damage caused by the abnormal weather, drought in particular.

Responding to this vital need, the CGPRT Centre has been implementing a three-year research project, "Stabilization of Upland Agriculture and Rural Development in El Nino Vulnerable Countries", since April 2000 in collaboration with partners from five countries, namely Indonesia, Malaysia, Papua New Guinea, the Philippines and Thailand.

During the last two and a half years, owing to the dedication of national experts and the regional advisor, we have been able to accomplish relevant studies, and now we are in the final stage of completing our report of each country, and of disseminating the results.

We have learned that there are various activities aimed at coping against abnormal weather risks that have been implemented by several organizations. Therefore, I do believe that it is very relevant and meaningful to exchange and to discuss the research results and the expertise obtained together, and to disseminate it.

Fortunately, owing to the mutual understanding and collaboration of the Department of Agriculture, the Philippines, the Australian Center for International Agricultural Research (ACIAR), the Japan International Research Center for Agricultural Sciences (JIRCAS) and the International Water Management Institute (IWMI), we can hold this joint workshop.

I would like to express my sincere thanks to all of these organizations, and also to Dr. Concepcion for his dedication in preparing this workshop.

I do believe that suggestions and comments from all of you will give us insightful ideas to provide policy implications on institutional and administrative preparedness against climatic risk for stabilizing rainfed agriculture and rural development, and to synergize national and

[*] Director, CGPRT Centre, Bogor, Indonesia.

international efforts concerning climatic risk for further collaboration, which are the main objectives of this workshop. I do hope for your active participation and discussion.

Finally, I would like to express my sincere appreciation to the Government of Japan for its support in funding the project.

Thank you very much.

Rationale, Objectives, and Benefits of the Joint Workshop

Rogelio N. Concepcion[*] *and Shigeki Yokoyama*[**]

El Nino induced weather abnormality, drought in particular, has become a regular part of the economic and environmental problems of many countries in Asia and the Pacific, especially in the equatorial western pacific region. The multi-faceted concerns of El Nino and the subsequent effects on water resources and its long-term impacts on land degradation, food production, human lives, the nation's economy and environment is a common concern and therefore, served as a common platform for the focal points of sustainable development of the region.

Food production in the region remains insecure due to the on-going changes in climate patterns and most especially, the increasing incidence of El Nino and La Nina, in addition to the usual patterns of dry spells and droughts. It could be worsened by the inefficient management of people and their respective natural resources.

Science has a way to manage and formulate plans of action to prevent, reverse, and rehabilitate areas and people affected by human-induced disasters. However, in dealing with natural disasters like El Nino and La Nina, scientists can best provide advisories and early warning systems to minimize damage but so far, none of the scientific knowledge can be developed to prevent or reverse the occurrence of climate abnormality itself.

Records indicate that during the last 100 years, there were about 23 events of El Nino and 15 events of La Nina. During the last 4 decades, it has been observed that incidences of El Nino increased from once every ten years to once every 3 years. Relatively weaker El Nino events occurred every 2 to 3 years and events that caused serious and widespread damage to crops, livestock and fishery sectors recur every 8 to 11 years. The impacts come in many forms, and each one has economic, social, and environmental impacts. Food and water supply to individual farm families are seriously impaired, causing them to migrate to nearby urban areas. Food security programs of some countries have to be reviewed and have to set aside scarce hard currency reserves to compete with other countries for whatever is available on the international market to augment their food reserves.

Prolonged and severe dry spells encourage widespread forest-fires, as happened in Indonesia, and the resulting haze affected the daily lives and health of many people, not only from Indonesia but also adjoining countries like Singapore and Malaysia. The Philippines, a country highly dependent on agriculture, was severely damaged by the last 1997-1998 El Nino. Some 74,000 hectares of food producing areas in 18 provinces were affected and the production of rice and maize decreased by as much as 27 per cent and 44 per cent respectively (expected effects of 2002-03 El Nino in the Philippines are shown in Table 1 and 2). El Nino parched the land and destroyed its cover and as the country was about to recover, within the next 2 to 3 years, or even the year after, La Nina, the other side of ENSO, brought too much rain and caused flash floods and once again damaged the crops, livestock, fisheries, and destroyed

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[**] Leader, ELNINO project, CGPRT Centre, Bogor, Indonesia.

whatever remaining properties there were of almost the same group of communities hit by the El Nino. Worse still, twin global events occurring in succession, cause serious soil erosion, siltation of the river systems and the accelerated mobilization and transfer of sediments loaded with pollutants into the river estuaries causing long term degradation of the marine grounds.

Several international and national research centers have been implementing projects which have a common goal, namely, enhancing food security and welfare of resource poor farmers under climatic risk through sustainable resource management and the stabilization of agricultural production. Although all of the projects are eventually seeking the development of farmer friendly appropriate technology/infrastructure and relevant policy measures coping with drought and environmental degradation, there are various approaches and focal issues are as wide ranging as socioeconomic aspects, climate forecasting/information system, water/soil management, etc. Given the strategic importance of the many lessons learned from each project, it is valuable and practical for all concerned to come together to exchange ideas and learn from one another.

The main objective of the workshop is to establish synergy in the implementation of these various climate related projects to enhance study strategy and provide the basis for the formulation of tactical and strategic plans that integrate common actions and therefore avoid overlap among projects. The expected benefits from participating in this joint workshop are, (i) to disseminate results of the project to a wider audience beyond the project countries; (ii) to gain knowledge and information for further implementation of the project; and (iii) to establish and strengthen wider links with relevant organizations for current and future activities.

Table 1. Effects of drought and El Nino 2002 in the Philippines

Planting Dates	Climate Situation	Impacts on Vulnerable Areas		Other Impacts
		Rainfed Rice/Upland Crops	Irrigated Rice	
January – April	Drought	Late crops	Late crops	Inadequate refilling of dams
1st – 3rd wk May 4th wk May	Drought Sporadic rain	Late crops	Late crops	Low water levels in Angat and Pantabangan
June	Rain	Normal planting	Normal planting	Refilling of dams
On or before July 15 Last half July	Rain/typhoons	Normal planting Late planting	Normal planting Late planting	Refilling of dams
August	Rain/typhoons	Late planting Standing crops	Late planting Standing crops	Refilling of dams
September	Early termination of rain	Harvest June planting Late planting	Harvest June planting Late planting (threatened)	Reduction of water stored in dams If only rain terminates, palagad is seriously threatened (those planted later than July 15th maybe lost)
October	El Nino	Reduced harvest for late crops	Harvest of late crops	No refilling of dams
November - December	El Nino	No crops	Palagad seriously threatened	No refilling of dams

Table 2. 2003 – Continuation of 2002 El Nino Episode

Planting Dates	Climate Situation	Impacts on Vulnerable Areas		Other Impacts
		Rainfed Rice/Upland Crops	Irrigated Rice	
January	El Nino	No crop	Palagad seriously threatened	No refilling of dams (Forest fire)
February – March	El Nino	No crop	Some palagad destroyed	No refilling of dams (Forest fire)
April	El Nino	No crop	Possibility of no planting	No refilling of dams (Forest fire)
May (land preparation planting)	El Nino	No crop	Possibility of no planting	No refilling of dams (Forest fire)
June				
1st half	El Nino weakens	No crop	Possibility of no planting	Angat, Pantabangan, Magat May dry up, unable to support rice crop production
2nd half	Rain Starts?	Start Planting	Reduction of crop area depending on stored water in dams	SSIP may not be operational Major dams in Mindanao may also be affected
July				
1st half	Rain	Normal planting	Normal planting	Refilling of dams
2nd half	Rain	Late planting	Late planting	Serious WS erosion
August – September	Typhoons/ Rain	Standing crops	Standing crops	Refilling of dams Serious WS erosion
October	Typhoons/ Rain	Standing crops	1st harvest/ standing crops	Dam is filled up (normalization) Serious WS erosion
December			Normalization	

Source: Bureau of Soil and Water Management, Department of Agriculture, the Philippines.

Assessing the Impacts of Climate Variability on Crop Production, and Developing Coping Strategies in Rainfed Agriculture

Felino P. Lansigan[*]

Introduction

Anthropogenic activities and internal stresses induced by natural variability of global biophysical processes have led to significant environmental problems including inadequate water resources and deteriorating, clean and dependable freshwater supply for human consumption and for agriculture. Water availability, in terms of its temporal and spatial distribution, is further exacerbated by climate variability which affects the human systems, the hydrologic cycle, and also food production systems in a particular area.

Water resource management in rainfed agriculture has important implications on food security and environmental integrity. Increased productivity in rainfed agriculture reduces the pressure on the limited land and water resources. Developments in efficient and effective management of water resources lend promise to increased crop production, improved livelihoods and food security in many rainfed areas. Water availability for agriculture, in terms of its temporal and spatial distribution, is expected to be highly vulnerable to climate variability.

Increasing water scarcity and water quality deterioration have continuously threatened human livelihoods and environmental systems, including rainfed agriculture in many tropical regions. Addressing the complex water resource issues requires that these challenges be approached in the context of their biophysical and socio-economic environment. IWMI (2000) presented the global water scarcity scenario for 2025 for biophysical and economic reasons considering the increasing need for water resources for agriculture, food and other water uses. Regions facing physical water scarcity are those areas that do not have sufficient water resources to meet the different water demands by 2025. Areas with economic water scarcity are those with enough utilizable water resources but where much more water will have to be developed by various means to satisfy the projected water requirements. The challenge to achieve water and food security in developing countries requires efficient management of water resources in the light of emerging water scarcity. The question of whether rainfed areas can contribute substantially to increased crop production to meet the growing food demand is becoming increasingly important as the competition among water uses and users escalates. Suitable areas, where climatic conditions are favorable for rainfed agriculture, need to be identified.

The latest scenarios on climate research studies (IPCC, 2001) suggest that anticipated future climate will be characterized by a temperature increase from 1.4^{o} C - 5.8^{o} C and changes in precipitation patterns with increased frequency and intensity of extreme weather events such as an increase in the occurrence of successive years of dry and wet periods, tropical cyclones, and typhoons. These hydrologic changes will have major impacts on human and natural systems

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as well as on rainfed areas in the tropics. Successive and prolonged occurrences of drought and floods will greatly affect the ability of rainfed agricultural areas to produce food, and to protect the integrity of the environment.

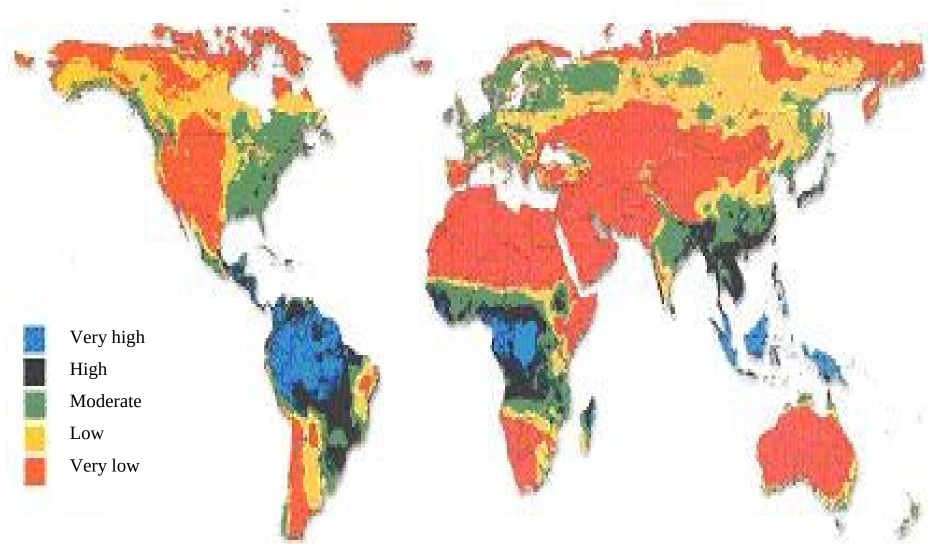
The reality of global climate change and climate variability has focused attention on the need to evaluate its effects and impacts on human and environmental systems including agricultural production systems, especially on food security in specific regions. Design and implementation of effective coping mechanisms requires an objective and scientific understanding of the effects and impacts so that appropriate adaptation strategies and mitigation measures can be formulated. Tackling the assessment of effects and impacts and identifying adaptation and mitigation measures needs a systematic approach that is built on better understanding of the processes in biophysical and socio-economic aspects of the environment, so that changes and consequences can be related to other processes. The systems approach allows the linking of changes at different levels such as changes in the basin level to the field level.

The objectives of the paper are (1) to present a systems analysis approach to evaluating effects and impacts of climate variability on rainfed agriculture at the basin and field scale levels; (2) to discuss recent research results on the analysis of climate variability and its impacts on crop production systems; (3) to present initiatives on coping with climate variability and changes in water and food systems; and (4) to rationalize the need for linking science and policy through knowledge-based policy formulation and decision-making in coping with and managing climate variability in rainfed agriculture and water food systems. Section 2 of the paper describes some results of previous assessment studies on climate change and climate variability based on field experiments and simulation modeling and analysis. Research and development activities including some global, regional and local initiatives to cope with and manage climate variability with particular focus on agriculture and food production systems are discussed in Section 3. Formulation of knowledge-based adaptation strategies and mitigation measures including policy design are presented in Section 4. The paper concludes with the emerging need for objective and scientific tools as components of a decision support system, the increasing necessity for capacity building, and the urgent call for cooperative and collaborative action as part of the overall strategy to manage climate variability.

Systems approach to analysis of climate variability and its effects and impacts on crop production systems in rainfed areas

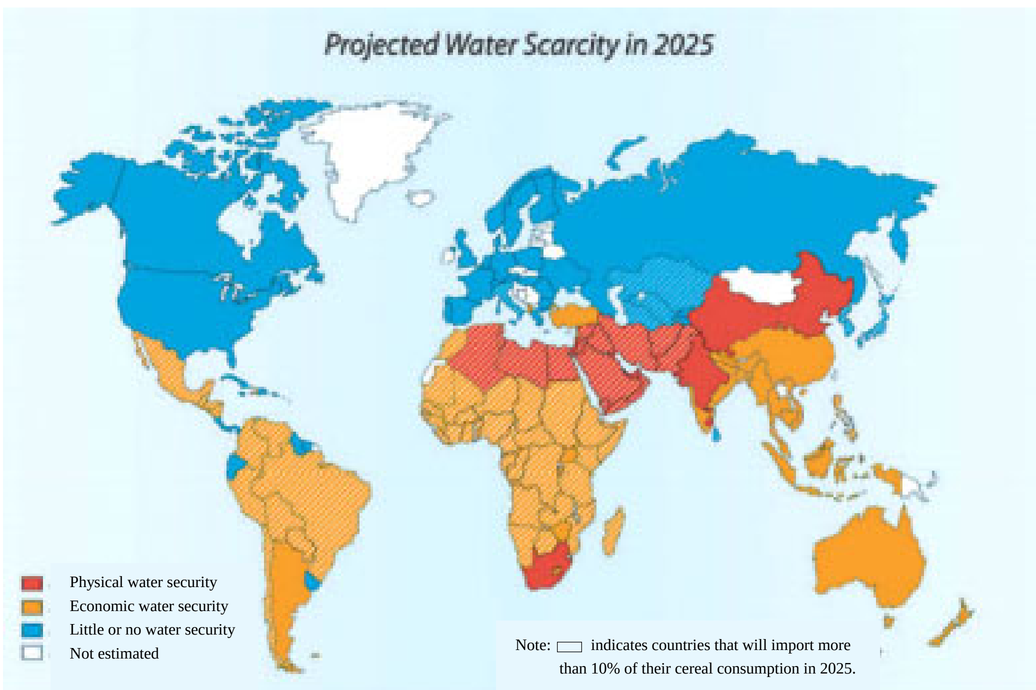
Assessments of climate-induced impacts and formulation of adaptation and mitigation measures should be analyzed at three different hydrologic scales, namely: global scale, basin scale, and field level. Potential areas for rainfed agriculture on the global scale are shown in Figure 1. It is estimated that at the global scale, 46 per cent of the earth’s surface is unsuitable for rainfed agriculture due to climatic constraints, and of the remaining 7 billion ha with the potential for rainfed crop production, only 4.7 billion is considered to be moderate to highly suitable (IWMI, 2000). It is also noted that those potential areas for rainfed agriculture are also the regions facing physical and economic water scarcity (Figure 2) where inadequate financial and human resources will limit the ability to explore supplemental water resources needed.

Figure 1. Potential areas for rainfed agriculture on a global scale



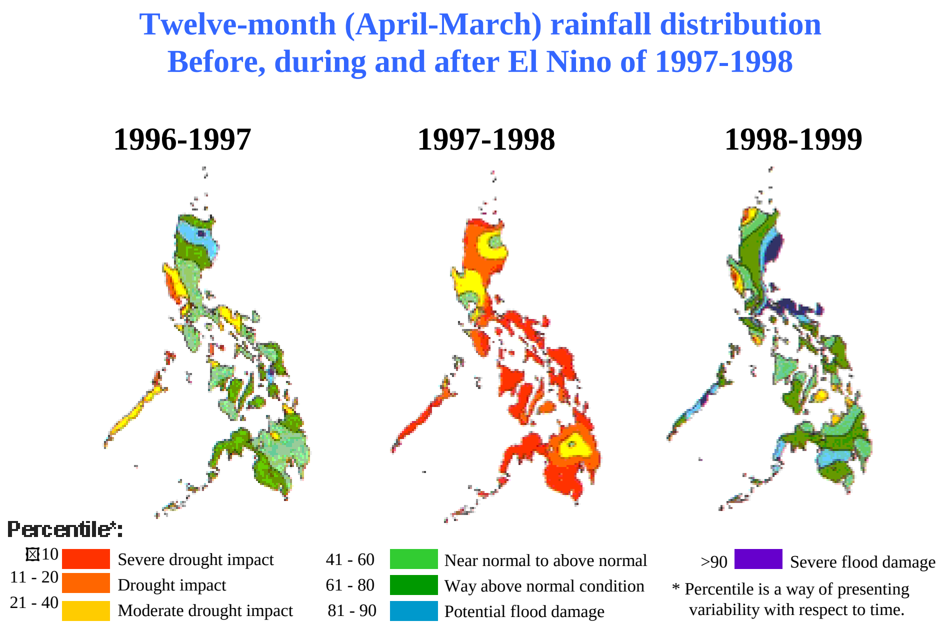
Source: IWMI, 2000.
Note: Preliminary estimates are currently being refined taking into account non-climate related factors (e.g. areas not available for conversion to agriculture).

Figure 2. Global water scarcity map



Source: IWMI, 2000.

Figure 3. El Nino of 1997-1998 in the Philippines



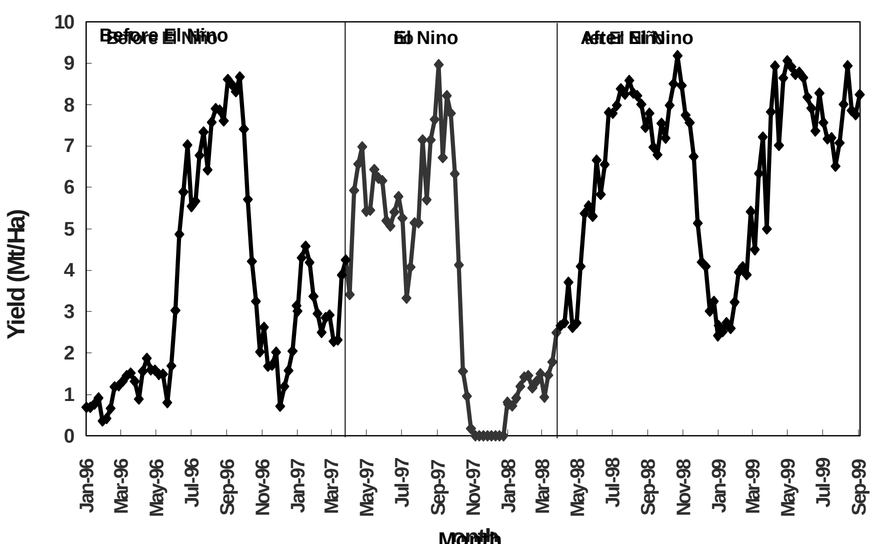
Source: PAGASA (2000).

At regional and national scales, wide variability in climate and the fluctuations in weather are important factors in crop production systems. Climate and weather determine the cropping and management systems, including the scheduling of crop production activities. Unfavorable weather remains to be a major cause of crop failure. During the 1997/98 El Nino for example, the Philippines lost more than PhP3.2B on corn production which primarily affected the two major corn growing provinces of Isabela and South Cotabato (Lansigan et al., 2002a). Monthly average rainfall data indicates moderate to severe drought conditions during the 1997/98 El Nino event (Figure 3). The figure shows that before and after El Nino, rainfall conditions in Isabela were above normal while South Cotabato conditions were near normal to above normal. During that year, Isabela experienced moderate drought to normal conditions, however, severe drought occurred in South Cotabato.

Advances in science and the development of systems research tools (e.g. simulation models, optimization techniques, geographic information systems and use of databases) have facilitated the integration of information and knowledge from different disciplines (see Aggarwal *et al.*, 1996 and Teng *et al.*, 1997). Dynamic process-based simulation models have been used in various practical applications at the global, regional and field levels. Ecophysiological simulation models have enabled the evaluation of effects of exogenous factors like weather in crop production for impact assessment studies (Matthews et al., 1995 and Horie, 1993). Climate risk and vulnerability of rainfed crop production systems to climate variability and change can be quantitatively evaluated. Combined use of simulation models with temperature gradient tunnel (TGT) experiments have greatly facilitated better understanding of the effects of change in the climatic environment on crop growth and development as well as crop yield (Lansigan, 1993 and Horie *et al.*, 1995).

Better understanding of processes via systems simulation modeling helps improve resource management in crop production. Crop simulation models are used to determine crop responses and predict crop performance under different environmental and management conditions. As a case study, analysis of corn yield gaps in the major corn growing areas in the Philippines was conducted which involved estimating crop yields considering weather, soil, genetic and management factors using the DSSAT CERES-Maize model parameterized for local corn varieties, and validated for different locations. CERES-Maize model simulates corn growth and yield, taking into account processes such as phenological and morphological development, biomass accumulation and partitioning. Minimum data on variety-specific genetic coefficients was determined, and local corn variety-specific coefficients were obtained from field experiments conducted in 2000-2001 at different locations, namely: U.P. Los Baños, Laguna; Isabela State University, Echague, Isabela; Central Mindanao University, Musuan, Bukidnon; University of Southern Mindanao, Cotabato; and Leyte State University, Baybay, Leyte. On-farm trials on farmers' fields were also carried out in Alcala, Pangasinan; La Carlota, Negros Occidental; Argao, Cebu; and Koronadal, South Cotabato. Varieties used were IPB Var 911, USM Var 5, ViSCA Var 2, CMU Var 12 and Cargill 818/Pioneer 3014 as a check variety. Variety-specific coefficients and local daily weather data (solar radiation, rainfall, minimum and maximum temperatures) covering the period from planting to harvesting were used to simulate corn yields across locations. Aside from assessing climatic risk to corn production, the study also revealed the extent of crop physiological and agronomic data gaps in corn research and development which have to be incorporated in rationalizing research priorities (Lansigan *et al.*, 2002b).

Figure 4a. Simulated corn yields in Isabela, Philippines before, during and after 1997-1998 El Nino.



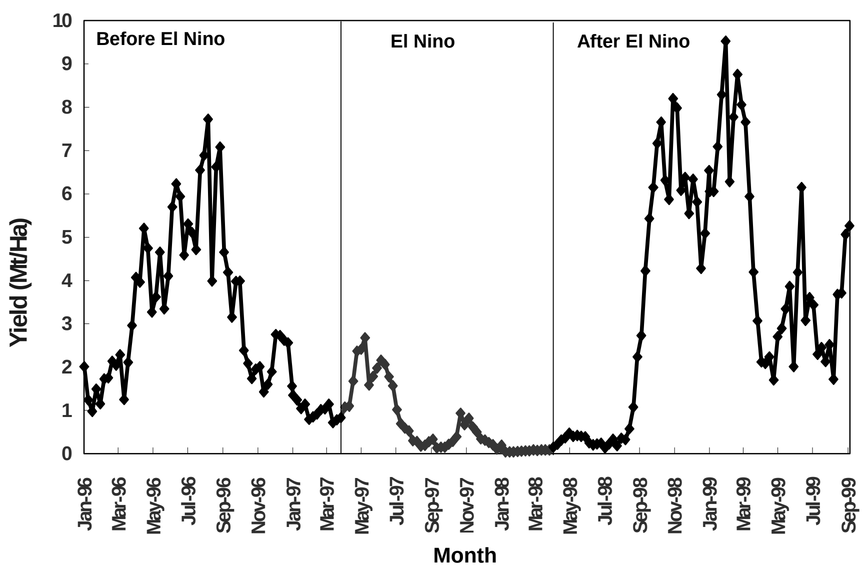
Source: Lansigan *et al.*, 2002a.

Simulated corn yields for Isabela (Figure 4a) and South Cotabato (Figure 4b) were determined at sequential weekly planting intervals using the daily weather data from 1996-1999 at the two sites (Lansigan *et al.*, 2002a). Traditionally, the planting calendar for Isabela is from June to July for the wet season (WS), and from November to December for the dry season (DS) cropping. Simulation analysis shows a wide planting window for Isabela even in the face of El Nino. This perhaps explains the moderate impact of the 1997/98 El Nino on corn production in the province. On the other hand, the planting schedule in South Cotabato is usually from March to April (WS), and August to September (DS). Simulated corn yields during the 1997/98 El

Nino were much lower than those before and after the said period. Trends also show that there was a very narrow window available for planting corn during El Nino that year. This may be attributed to the severe impact of the 1997/98 El Nino in that province.

Crop simulation models can provide estimates of corn yields as affected by various factors such as weather, and can be used to evaluate the effects of climate variability on crop growth and development. For instance, effects of temperature increase coupled with a double CO2 level on rice yield using simulation analysis had been reported in earlier studies (e.g. Lansigan, 1993; Horie, 1993; Matthews *et al*., 1995). Simulation results indicated a reduction in rice yields due primarily, to increased spikelet sterility which is highly sensitive to an increase in temperature (e.g. Horie *et al*., 1995). Similarly for corn, the adverse effects of El Nino are inevitable and prolonged drought spells, coinciding with the tasseling stage may lead to extensive yield losses. These results illustrate that the occurrence of extreme climate events coinciding with critical periods of crop growth and development can significantly reduce crop yields. Thus, timing of cropping periods with advanced seasonal climate forecasts are critical in coping with climate variability.

Figure 4b. Simulated corn yields in South Cotabato, Philippines, before, during and after 1997-1998 El Nino



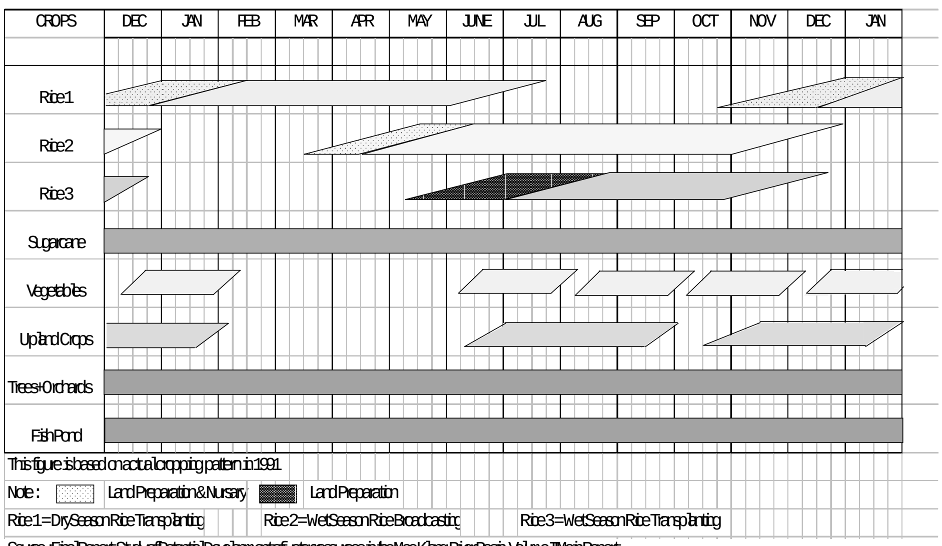
Source: Lansigan *et al*., 2002a.

Climate variability affects the availability of water in the basin in terms of spatial and temporal distribution of water for crop production. At the basin scale, variability in climate alters the basin hydrology which will bring changes in water availability for various water uses and users (e.g. agricultural, hydropower, domestic and industrial, and environmental). Changes in water distribution and allocation can be evaluated and their impacts assessed using simulation models e.g. STREAM Model (Aerts *et al*., 1999) and SWAT model (Neitsch *et al*., 2001). Use of a basin level model enables the evaluation of changes in the spatial and temporal distribution of water in the catchment. Field scale models (e.g. SWAP: Soil, Water, Atmosphere and Plant Model; Bastiaanssen *et al*., 1996) can be used to relate changes in the basin with changes and processes in the crop production system and environment. The analysis will be useful in designing an appropriate cropping calendar, cropping sequence, and crop management system in the face of anticipated climate conditions. It is also important to recognize and consider in impact assessment and analysis, the transient nature of climate variability and the uncertainties in the simulation modeling associated with input data used.

Coping with and managing climate variability in rainfed agriculture

Some rationale adaptation and mitigation measures to climate variability are being practiced in different areas at various levels. Adjusting the cropping calendar based on crop simulation studies and considering the risks involved is one adaptation strategy to manage climate variability in crop production. Figure 5a shows the typical cropping calendar for various crops in the Mae Klong river basin in west central Thailand. Altering the cropping period in the face of forecasted climate conditions for the growing season is one option to mitigate the effect of extreme climate variability such as the El Nino phenomenon. This requires timely and accurate advanced seasonal forecasts of climate and weather to guide in changing or adjusting the planting and growing period.

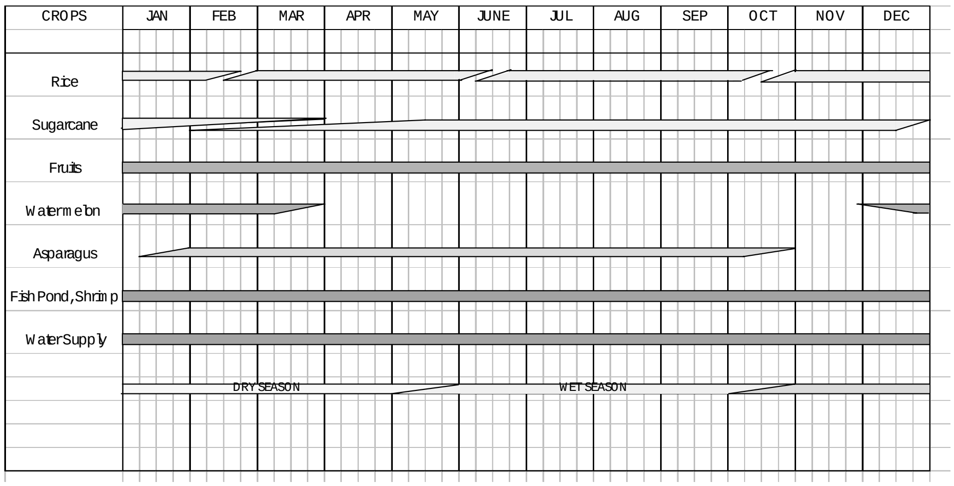
Figure 5a. Typical cropping calendar in Mae Klong, Thailand



Source: Final Report, Study of Potential Development of water resources in the Mae Klong River Basin, Volume II Main Report.

Modifying the cropping systems in terms of changing the variety of crops or considering entirely different crops to grow, is another adaptation to climate variability. Drought-tolerant crops or heat-resistant crop varieties may be planted which are more adapted to warmer or drier conditions. The genetic resources of crops and seeds in the germplasm collections may be screened to determine sources of resistance to heat and water stress as well as compatibility with new agricultural technologies such as use of less water in crop production. Figure 5b shows the current cropping calendar in Song Phi Nong area within Mae Klong basin when adequate irrigation water is available.

Figure 5b. Cropping calendar when irrigation water is available



Source: Song Phi Nong Irrigation Project.

Use of crop decision support systems in managing climate variability

Crop simulation models such as InfoCrop (Aggarwal *et al*., 2002), CROPWAT (FAO, 1992), and DSSAT (Tsuji *et al*., 1998) are now part of decision support systems (DSS) in resource management (Matthews and Stephens, 2002). DSS has facilitated the objective assessment of the effects of climate variability on crop production systems. User-friendly computer simulation models have facilitated the task of optimizing crop growth and deriving recommendations regarding crop management. They can also be used to evaluate and design adaptation and mitigation measures to cope with climate variability. These DSS tools provide an objective approach to simulate effects of soil, weather, management as well as pest factors on crop production. They can also be useful in assessing economic risks and environmental impacts associated with crop production including water and nutrient management, climate variability and change. However, while DSS's have been applied successfully in some practical problems, these tools should be used with caution because of the risks and uncertainties associated with the reliability of models used or some components of the models as well as on the reliability and uncertainties of the input data including weather and soil data.

Crop insurance to manage climate variability-induced risk

Potential damage to crop production and yield loss due to weather, are partly alleviated by providing crop insurance coverage to farmers. However, current crop insurance policy is based solely on the cost of production with little or no consideration to the differences and extent of environmental risks, which are location-specific and time-dependent. In a related case study (Lansigan, I.C.G. *et al*., 2002), risk in corn production due to weather and climate variability for estimating crop insurance premiums was evaluated using an ecophysiological CERES-Maize crop model parameterized and validated for a local corn variety (IPB Var 911) based on field experiments in two selected locations in the Philippines, namely, Isabela and South Cotabato representing different climatic types. Crop variety-specific genetic coefficients and available historical daily weather data such as rainfall, solar radiation, maximum and minimum temperature covering the period from planting to harvesting were used to simulate corn yields in different locations. Probability distributions of crop yields and probabilities of crop failure (i.e. yield below certain level) are estimated using the relative frequencies of simulated yields for various planting dates. Different yield distributions and yield probabilities obtained using simulation models indicate that risks to corn production due to weather and climate variability vary across locations, and at different planting periods. Quantified risk levels provide useful information in formulating policy for crop insurance coverage to assist agricultural banks and insurance companies in processing applications for loans and insurance. The study also shows that there is a need to review the policy on crop insurance premiums being levied across different locations. Figures 6a and 6b shows the probability distributions of corn yields in different locations (Isabela and South Cotabato) which provide a useful basis for determining insurance premiums for crop insurance coverage across sites.

Figure 6a. Probability distributions of simulated corn yields for different months of planting in Isabela, Philippines

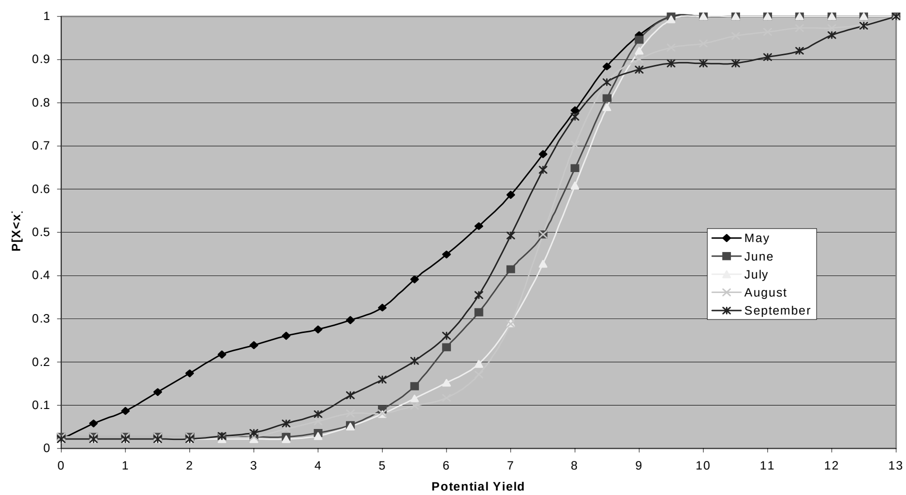
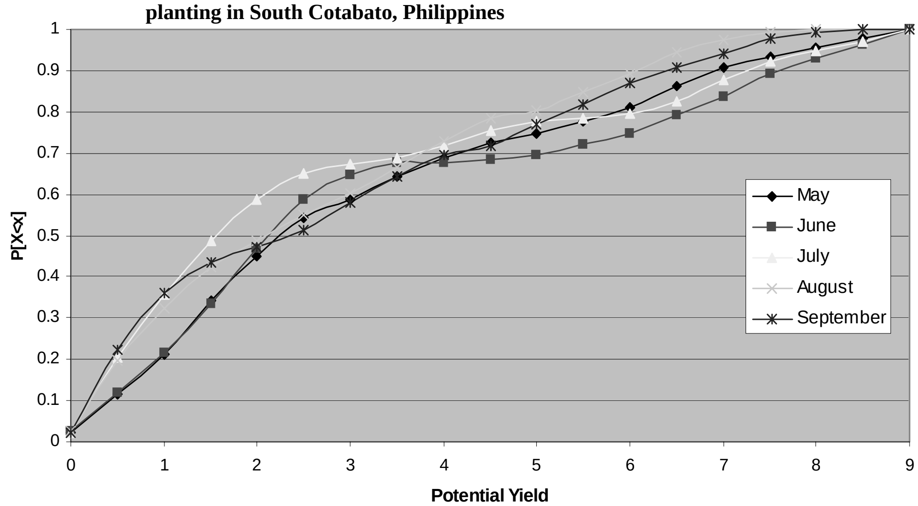


Figure 6b. Probability distributions of simulated corn yields for different months of planting in South Cotabato, Philippines

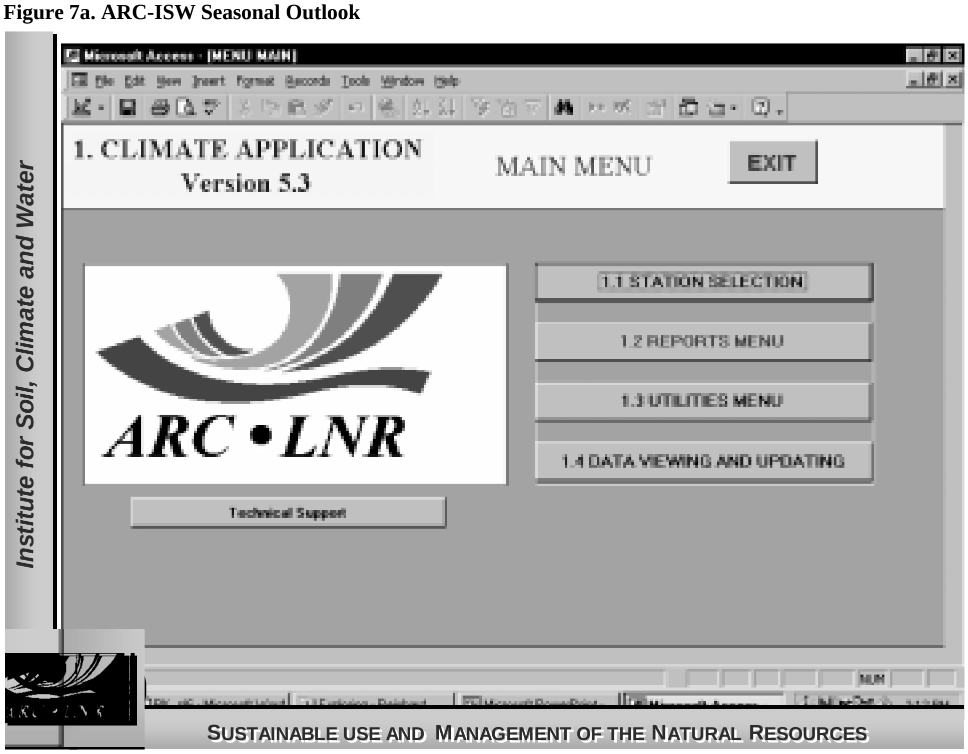


Source: Lansigan, I.C.G. *et al*., 2002.

Advanced seasonal outlook and crop forecasting

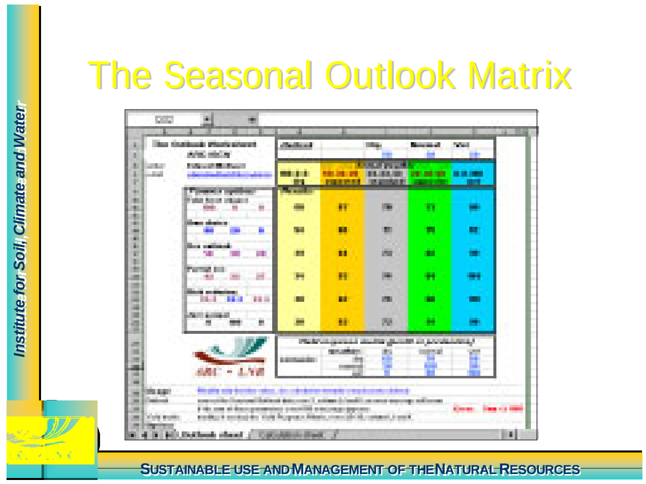
Advances in systems research tools and recent developments in climate research and related studies provide opportunity to predict or forecast seasonal climate and weather up to a certain lead-time and with reasonable accuracy. Forecasted weather conditions under the predicted seasonal climate, serve as inputs to a DSS which provides information in terms of appropriate management actions to take, considering the climatic risk (and even economic risk) involved. The system developed and being implemented in South Africa by the Institute for Soil, Climate and Water (ISCW) is a good example of practical application of simulation models for decision making and extension (Kuschke, 2002). ISCW Seasonal Outlook system provides interpretational values to the available agro-meteorological data from the weather agency, and the probabilistic analysis available by estimating seasonal weather conditions and assessing potential crop responses under the predicted environment. Advisories on seasonal outlook and crop management responses under dry, normal and wet conditions as well as cropping or management plans are generated. Analysis and comparison of actual results versus projected outlooks are also included (Figures 7a and 7b). Operationally, the South African Weather Service produces and disseminates a monthly probabilistic forecast. These are compiled by consolidating various seasonal forecast models. Rainfall probabilities are presented as terciles of outcome (i.e. per cent above normal, per cent near normal, and per cent below normal). The objective of the seasonal outlook is to provide the user with an estimation of potential results under various weather conditions and cropping management plans.

Figure 7a. ARC-ISW Seasonal Outlook



Source: Kuschke, 2002.

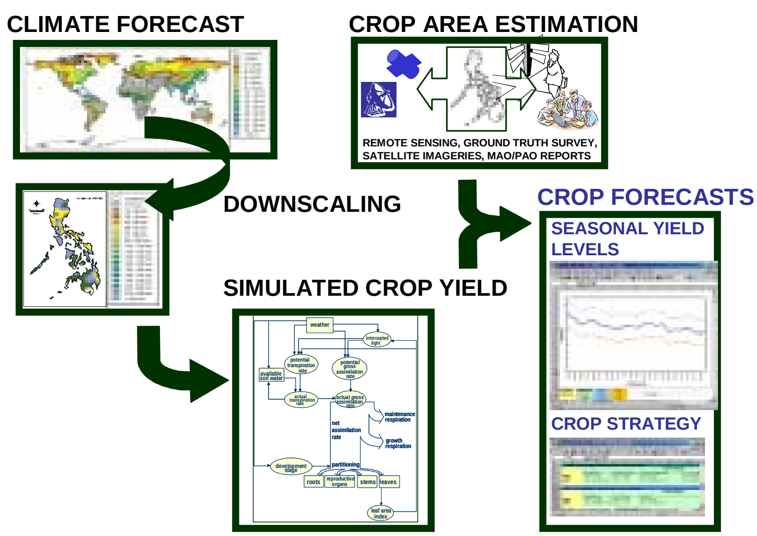
Figure 7b. Output of the ARC-ISCW Seasonal Outlook



Source: Kuschke, 2002.

A similar crop forecasting system is now being developed and will be implemented at the Department of Agriculture in the Philippines. The system involves crop yield forecasting using advanced seasonal climate forecasts, a process-based crop simulation model, remote-sensed data on crop area, and geographic information systems (Figure 8). The procedure requires at least 3 months advanced climate information which is downscaled to a specific location. The downscaled daily weather data will be inputted into a crop model for provincial yield estimation. The methodology integrates the use of systems tools in delivering crop yield forecasts for the Philippines. The knowledge-based crop forecasting systems hope to have a big contribution and impact in decision making, especially in implementing programs on staple crops such as rice and corn. Potential users of outputs of the crop forecasting system include the livestock and feed milling industries, producers and traders, and policy makers.

Figure 8. Systems approach to crop forecasting at DA, the Philippines
Figure 8.



Some initiatives on managing climate variability

There are essentially a number of international research initiatives related to the assessment of the effects and impacts of climate variability and change on water and food systems as well as on the human environmental system. The International Geosphere-Biosphere Programme (IGBP; http://www.igbp.kva.se) is an international research program whose aim is to develop a better understanding of the global environment and how it is changing through time. The International Human Dimensions Programme of Global Environment Change (IHDP: http://www.ihdp.org) is concerned with the effects and impacts of global change, and on how human systems adapt and interact with a changing environment. Adaptation and mitigation aspects are major issues of interest to IHDP. The World Climate Research Programme (WCRP; http://www.wcrp.org) involves research studies on atmosphere, climate and weather that greatly affect the environment. IGBP, IHDP and WCRP work together with other global environmental change programmes to collaborate on core projects, which address major issues of global sustainability including water resources, food systems and the carbon cycle.

The joint Global Project on Carbon (http:/www.gaoms.sr.unh.edu/cjp/) was launched to have a better understanding of the entire carbon cycle including the issue of carbon sequestration. The project on “Global Environmental Change and Food Systems (GECaFS; http://www.gecafs.org) was initiated to analyze how global environmental change affects food provision and vulnerability of different social groups in different regions as they adapt to cope with global environmental change, and on how these adaptations feedback into these changes. The research project on water resources is concerned with the impacts of global environmental change on local and regional water systems as well as on feedback mechanisms and sustainability of water resource systems.

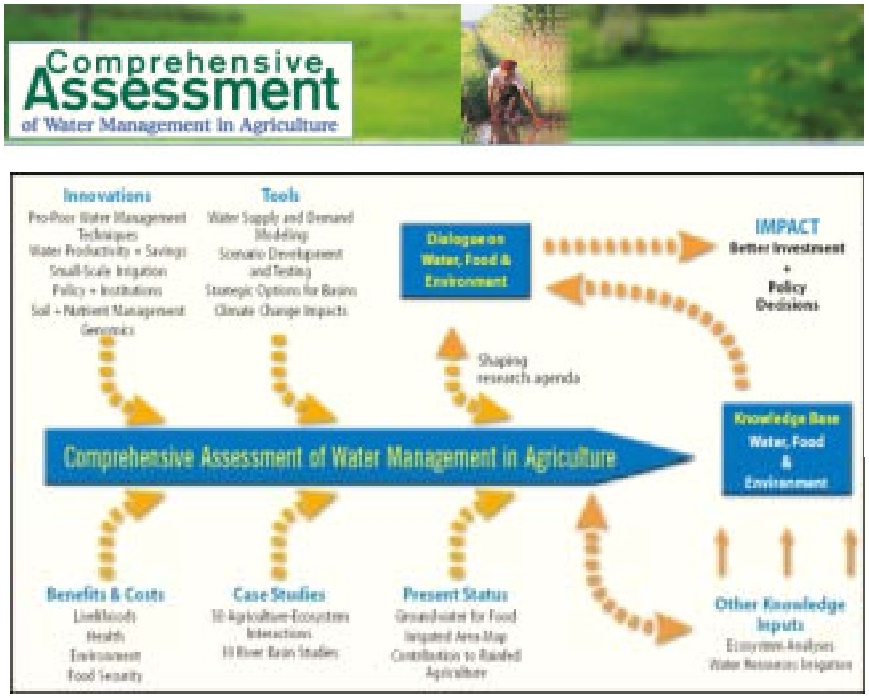
The CLIMAG (Climate Prediction and Agricultural Productivity) project was initiated to study the predictability of seasonal climate, and how this advanced information can be used by farmers to assist and make decisions regarding crop management. Case studies have been conducted to demonstrate the applicability and use of advanced information in improving the management of crop production systems in rainfed areas.

The Consultative Group for International Agricultural Research (CGIAR) has also launched related activities such as the Comprehensive Assessment of Water Management in Agriculture, and the Challenge Program on Water and Agriculture. The main objective of the Comprehensive Assessment of Water Management in Agriculture is to evaluate the potential to grow more food with less water, such that rural poverty is reduced, and improved human and environmental systems are sustained. The components and main activities of the assessment program are illustrated in Figure 9.

On the other hand, the CGIAR Challenge Program on Water and Agriculture aims to catalyze the effective and efficient improvements of water productivity in food production systems in a manner that is “pro-poor, gender-equitable, and environmentally sustainable.” Details of these initiatives and related activities can be viewed at CGIAR’s website (http://www.cgiar.org).

Collaboration and cooperation between the research programmes and the national research and development institutions and local researchers and experts will be useful and beneficial to furthering better understanding of climate variability. This understanding will contribute substantially to designing strategies to increase the flexibility of human, water and food systems to respond to extreme climate events such as the El Nino and La Nina phenomena, floods and droughts.

Figure 9. CGIAR Comprehensive Assessment of Water for Agriculture



Source: CGIAR, 2002.

Linking science and policy in adaptation strategies and mitigation measures to climate variability

It has become increasingly important to apply science in designing and developing knowledge-based policy analysis in addressing climate variability in rainfed agriculture.

As evident in previous sections, recent advances have increased our scientific understanding of processes of crop growth and development which allow more rational, efficient and effective adaptation and mitigating measures to be employed. For example, adjusting the cropping calendar and modifying the cropping systems to adapt to changes in the environment would require consideration of the suitability of the variety or the crop under the particular climate scenarios. This involves analysis of the characteristics and potentials of the crops and/or the varieties in a given location.

Similarly, developing new crop genotypes resistant to stresses and related to climate variability, such as crops or varieties which are drought resistant, heat tolerant, more water-use efficient, etc. involves rationalizing the national research and development agenda in agriculture, particularly on plant breeding, germplasm collection and genetic improvements. Research is needed to define the current limits to heat resistance and feasibility of manipulating such attributes through modern genetic techniques.

Crop insurance coverage may also be provided, including agricultural loans to support farmers affected by climate variability. Climate-induced risk in crop production should be evaluated more objectively. The current practice of charging a uniform crop insurance premium across locations with different risk levels should be reviewed. Simulation models parameterized and validated under different locations can be applied to evaluate risk.

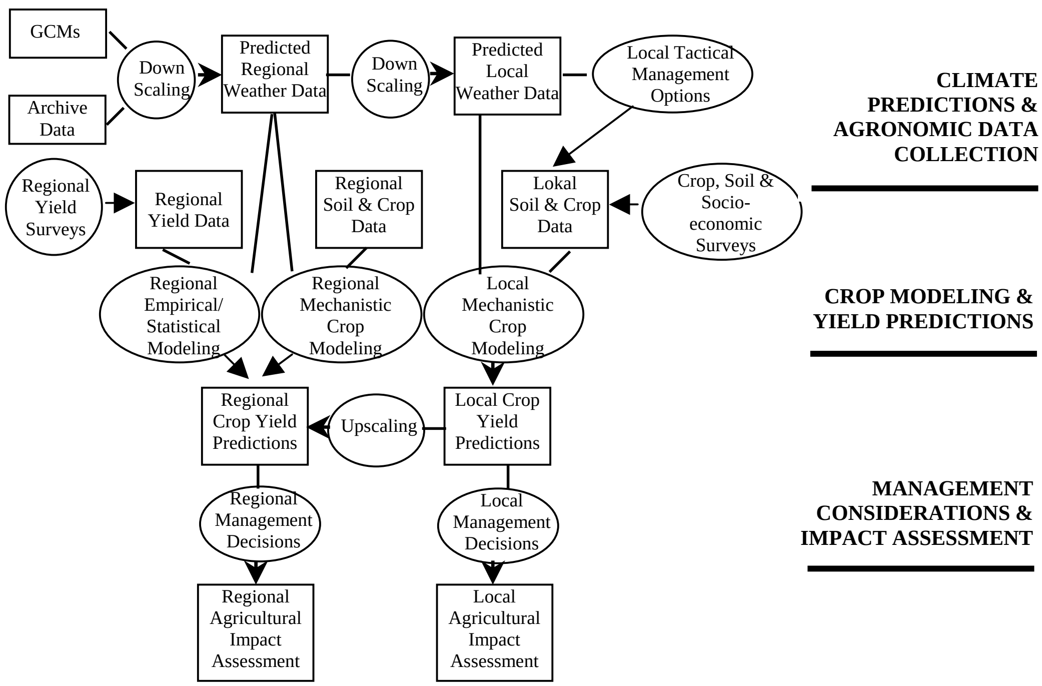
Climate variability and change, impinge on diverse, complex and dynamic forms of environmental disasters such as floods, droughts, typhoons, heat waves and storm surges. As mentioned earlier, extreme weather events are likely to become more frequent and intense in the future. Changes in storm tracks are also possible as evidenced in recent years. Thus, a wide range of precautionary measures at regional and national levels including awareness, perception and acceptance of risk and uncertainty factors in regional communities is imperative. This is to avert or reduce the impacts of such disasters on the economic and social environments, especially in rainfed areas of the tropics. The delegations from the 11 countries who participated in the Asian Ministerial Roundtable Dialogue on Water Issues and Challenges, 20-21 May 2002 in Bangkok, Thailand (see e.g. http://www.iwmi.org) have strongly indicated in a joint statement released during the conference, the emerging and urgent need for establishing an early warning system for disaster management, and for networking and collaboration among research and development institutions in the region.

Concluding remarks

The wide range of significant effects and impacts of climate variability on crop production systems in rainfed areas necessitates that a systems approach be applied. This approach will be useful in designing and developing appropriate, efficient and cost-effective adaptation and mitigation strategies and measures to cope with climate variability. Process-based simulation models (or ‘tools’) and databases are being developed and organized into a “toolbox” for smallholder land and water management to assist in promoting knowledge-based management decisions using systems approaches in collaboration with researchers and intended users of the tools (Penning de Vries and Lansigan, 2002b).

While empirical studies and impact assessments have been conducted, it appears that these are not readily accessible, and an integrative analysis to synthesize some generic guidelines across different locations for impact assessment as well as adaptation and mitigation analysis is not possible. It is becoming increasingly important to build the capacity of the use of scientific assessment procedures, and applications of objective methodologies in assisting policy design and formulation and decision-making. This may include promoting adjusted or revised crop production systems including water management, subsidies and support like crop insurance, etc. to cope with and manage climate variability (Figure 10). Cooperative and collaborative actions on coping with climate variability and change in agricultural production systems to increase the flexibility of the systems at different levels are imperative. These activities may involve data and information exchange among concerned agencies within the country and in the region, sharing of knowledge and expertise, and also testing new methodologies. Integrated planning to address the issue of climate variability and extreme events is indeed a challenge within institutions in the country and in the region. It is also equally important that all stakeholders including planners, policy makers and the public are informed of the impacts and consequences as well as of the appropriate adaptation and mitigation measures in order to promote preparedness, resilience and flexibility to climate variability.

Figure 10. Framework for climate variability, crop forecasting and impact assessment



References

Aerts, J.C., J.H. Kriek and M. Schepel, 1999. STREAM, Spatial Tools for River basins and Environment and Analysis of Management options. Physics and Chemistry of the Earth, Part B. Elsevier Science 23(3): 345-354.

Aggarwal, P.K. et al., 2002. InfoCrop: A User-friendly System for Applications of Crop Models (version 1.09), New Delhi, India: IARI.

Aggarwal, P.K., F.P. Lansigan, T.M. Thiyagarajan and E.G. Rubia, 1996 (Eds.) Integrating Simulation Modeling in Rice Research. SARP Research Proceedings, Wageningen: AB-DLO; Los Baños, Philippines: IRRI.

Bastiaanssen, W.G.M, R. Singh and S. Kumar, 1996. Analysis and recommendations for integrated farm water management in Haryana, India: a model approach. Report No. 118, Wageningen: Alterra Green World Research.

FAO, 1992. CROPWAT: A computer program for irrigation planning and management. Irrigation and Drainage Paper No. 46. Rome.

Horie, T., 1993. Predicting the effects of climate variation and elevated CO2 on rice yield in Japan, Journal of Agricultural Meteorology 48:567-574.

Horie, T., M.J. Kropff, H.G. Centeno, H. Nakagawa, J. Nakano, H.Y. Kim and M. Ohnishi, 1995. Effect of anticipated change in global environment in rice yields in Japan. *In* Peng, S., K.T. Ingram, H. Nueue, and L.H. Ziska (eds.). Climate Change and Rice, Berlin Heidelberg, Springer-Verlag.

IPCC, 2001. Intergovernmental Panel on Climate Change Third Assessment Report (TAR), Washington D.C., USA.

IWMI (International Water Management Institute), 2000. World water supply and demand in 2025. *In* Rijsberman, F. (ed). World Water Scenario Analyses, London, U.K: Earth Scan Publications.

Kuschke, R., 2002. A tool to evaluate long-range weather forecasts under various cropping plans. South African Agricultural Research Council Institute for Soil, Climate and Water.

Lansigan and J. L. Orno, 1993. Simulation analysis of risk and uncertainty in crop yield due climatic variations and change. *In* B.A.M., Bouman et al. (eds.) Agro-ecology of Rice-based Cropping Systems, SARP Research Proceedings, Oct. 1993, Wageningen, The Netherlands.

Lansigan, F.P., 1993. Evaluating the effect of anticipated climate change on rice production in the Philippines. Journal of Agricultural Meteorology 48:779-782.

Lansigan, F.P.**,** W.L. delos Santos and J.L Orno-Coladilla, 2000. Agronomic impacts of climatic variability in the Philippines, Journal of Agriculture, Ecosystems and Environment 82:129-137.

Lansigan, F.P., W.L. delos Santos, M.T. Fabellar and R.G. Perez, 2002a. Trends in simulated corn yields during El Nino in the Philippines. Proceedings, Crop Science Society of the Philippines Annual Conference, April 20-22, 2002, Tagbilaran City, Philippines.

Lansigan, F.P., W.L. delos Santos, M.T. Fabellar and R.G. Perez, 2002b. Estimating corn yields in selected locations in the Philippines using an ecophysiological process-based crop simulation model. Proceedings, National Corn R&D Conference, Nov. 27-29, 2002, Quezon City, Philippines.

Lansigan, I.C.G., F.P. Lansigan and M.T. Fabellar, 2002. Evaluating weather-induced risk in corn production for crop insurance using an eco-physiological crop simulation model. Proceedings, National Corn R&D Conference, Nov. 27-29, 2002, Quezon City, Philippines.

Matthews, R.B. and W. Stephens (eds.), 2002. Crop-Soils Simulation Models: Applications in Developing Countries, Wallingford: CAB International.

Matthews, R.B., M.J. Kropff, D. Bachelet, and H.H. van Laar, 1995. Modeling the Impacts of Climate Change on Rice Production in Asia, Philippines: IRRI and CABI.

Neitsch, S.L. et al., 2001. Soil and Water Assessment Tool (SWAT).

Penning de Vries, F. and F.P. Lansigan, 2002a. Site- and situation-specific management for smallholder agricultural enterprise. Keynote paper, Proceedings of International Agronomy Congress, November 2002, New Delhi, India.

Penning de Vries, F. and F.P. Lansigan, 2002b. Smallholder Toolbox for Land and Water Management. Proceedings of the Workshop, July 18-19, 2002, Bangkok, Thailand.

Teng, P.S., M.J. Kropff, H.F.M. ten Berge, J.B. Dent, F.P. Lansigan and H.H. van Laar (eds.), 1997. Applications of Systems Approaches at the Farm and Regional Levels: v. 1, Dordrecht, Netherlands: Kluwer Academic Publishers.

Tsuji, G.Y., G. Hoogenboom and P.K. Thornton, 1998. Understanding Options for Agricultural Production, Dordrecht: Kluwer Publisher.

Seasonal Climate Forecasts and Decision Support Systems for Drought Prone Agriculture: A Case Study Based on the Development and Application of the Rainman Climate Analysis Software

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Abstract

This paper considers the role of decision support systems to apply seasonal climate information in agriculture by documenting the development and application of the Australian Rainman computer package as a case study. Rainman aims to develop knowledge and skills for managing climate variability in agriculture by analysing effects of the El Nino/Southern Oscillation (ENSO) on rainfall to derive probability-based seasonal climate forecasts. The two main seasonal forecast tools used in Rainman are the Southern Oscillation Index (SOI) and an index of Sea Surface Temperature (SST). The Rainman version 4 prototype is due for release and has improved seasonal forecast analyses and capacity for world-wide mapping of seasonal rainfall information at district and regional scales. There has also been interest in applying seasonal forecast technology to water supplies and irrigation systems and has led to developing the StreamFlow supplement for analysis of streamflow and run-off data.

A central principle used in developing Rainman has been to include only seasonal forecast methods that have been well established and accepted by the scientific community and national organizations with responsibility in seasonal climate forecasting. Thus, the participative process to define and review Rainman has been an important element in the development of Rainman as a decision support product. Peer review is a necessary part of the quality assurance process in developing decision support systems.

In communicating knowledge of risk, we have found that cumulative probability distributions work well for scientists. However, in communicating with the farming community, other ways of expressing risk have been more effective such as frequency plots, pie charts, box plots and time series. Rainman analyses follow accepted scientific conventions by applying several statistical tests to seasonal forecasts so that: (a) users have some guidance regarding the statistical reliability of the forecast information, and (b) duty of care is discharged in providing forecast information to users.

The Rainman case study shows that software is an effective way to provide people with climatic information because it can be detailed but easy to use, comprehensive and locally relevant. Learning to use ENSO information is maximised by combining "hands-on" learning with the software with participation in a workshop where people share ideas and experiences. Benefits of using Rainman include improved knowledge and skills about the variable climate and seasonal climate forecasts, enhanced agriculture and resource management decisions, and reduced climate risk exposure.

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Introduction

The El Nino/Southern Oscillation (ENSO) component of climate variability has large and often severe impacts on both agricultural production and the livelihood of many people (Nicholls, 1985; White, 2000; Hammer *et al*., 2001), and in 1997/98, the impacts of El Nino in SE Asian countries caused widespread drought and fires with estimated losses exceeding $20 billion. While ENSO has impacts on a global scale (Stone *et al*., 1996), the timely knowledge of expected rainfall at a local level is an essential part of decision-making for farmers, resource managers and business people. Organizations in Australia involved with disseminating climatic information have recognised that people gain information, knowledge and skills in many ways, and have thus sought to build a rich diversity of information and decision support pathways. These pathways range from raising awareness, attitudes and aspirations of people to more comprehensive development of knowledge and skills through a breadth of decision support systems such as:

- Printed resources (books, pamphlets) eg. *Will It Rain?* (Partridge, 1991, 2002a, 2002b)
- Subscription services eg. Seasonal Climate Outlook (National Climate Centre)
- Mass media eg. TV services, radio, newspaper, magazines and journals
- Phone and fax services eg. Weather by Fax, FarmWeather, SOI Hotline, Farmfax
- PC Software eg. Grassman (Scanlan and McKeon, 1990 and Clewett *et al.*, 1991), Wheatman (Woodruff, 1992), DroughtPlan (Stafford-Smith *et al*., 1998; Cobon and Clewett, 1999), StreamFlow (Clarkson *et al.*, 2000), Whopper Cropper (Nelson *et al*., 2002)
- Web sites eg. LongPaddock (www.LongPaddock.qld.gov.au) Met Net (www.bom.gov.au), SILO (www.bom.gov.au/silo/), CVAP (Climate Variability in Agriculture Program) (www.cvap.gov.au), Qld Centre for Climate Applications (www.dpi.qld.gov.au/climate/).
- Education processes eg. The *Climate and Your Farm* Home Study Course (Brouwer and George, 1995; Bayley, 2000), *Managing for Climate* workshops (O'Sullivan and Paull, 1995) and *Developing Climate Risk Management Strategies* (ANTA, 2000).

While further analyses of the above are given by Clewett *et al*. (2000b), a general review of decision support systems is given by Stuth and Lyons (1993) and the text by Hammer *et al.* (2000) provides a recent review of the application of seasonal climate forecasting in Australian agriculture and natural ecosystems. In this latter text, the paper by White (2000) highlights the potential value of seasonal climate forecasts to agriculture, but also recognises the substantive difficulties that people have in applying probability-based information to management decisions. The papers by Hammer (2000) and Nelson *et al.* (2002) present the view that a major function of decision support systems is in the role of discussion support, designed to facilitate dialogue about management practices.

The purpose of this paper is to discuss the development and application of the Rainman package as a specific case study in the more general theme of developing decision support systems for the application of probability-based seasonal climate forecasts in agriculture. The following sections discuss:

- the challenge and historical factors leading to development of Rainman
- participative processes necessary for development of decision support
- presentation of results that recognise the needs of different users
- the scientific basis of seasonal forecast methods used in Rainman
- tests on seasonal forecast skill
- peer review and adoption

- benefits from development and application of Rainman

The challenge for rainman and its history of development

The challenge in developing Rainman as a decision support package was to find a practical way to lift the capacity of people to achieve better management of climatic risks so that opportunities for sustainability and profit in agricultural systems were enhanced. The key parts of this challenge were:

- developing a collaborative ethos and a participative problem-solving style so that Rainman represented the collective views of the scientific community and the needs of industry
- raising awareness of climate variability issues including the atmospheric and oceanic processes causing the El Nino/Southern Oscillation (ENSO) phenomenon
- enhancing knowledge of seasonal climate forecast technology and raising skills to apply this knowledge in agricultural decisions
- raising awareness and appreciation for the role of computer software in agricultural management, and successfully developing and marketing a software package and educational processes.

Rainman version 1 (Clarkson and Owens, 1991; Clewett *et al*., 1993) with its companion book *Will It Rain?* (Partridge, 1991) was developed in response to demand from many people concerning access to climate records and analyses of rainfall concerning the effects of ENSO. While this first publication was developed to meet the needs of Queensland, the popularity of the package and demand from other states soon led to development of version 2 for all of Australia (Clewett *et al*., 1994; Clewett *et al.* 1996). This was released in October 1994 with a second edition of *Will It Rain?* Further demand then led to release of a Windows version (Australian Rainman version 3) in June 1999 which also included a large the reference section and many improvements to the analyses and graphics (Clewett *et al*., 1999). The Rainman version 4 prototype is due for release and has improved seasonal forecast analyses and capacity for world-wide mapping of seasonal rainfall information at district and regional scales. It is being developed through the ACIAR-funded project "*Capturing the benefits of seasonal climate forecasts in agricultural management*" and has been used as a decision support resource in a series of workshops with strong support from participants in this project in Indonesia, Zimbabwe and India (George and Selvaraju , 2002). The project aims to:

- evaluate a range of seasonal climate forecast signals and statistical methods
- identify relationships between climate indicators and impacts on agriculture
- assess the value of the forecasts at key decision points in the agricultural system
- develop and evaluate (within case studies) a range of decision support systems; including participative workshops and learning packages, agricultural models, and an international version of the Australian Rainman software package
- publish and disseminate results from the case studies on ways to improve farm management so that potential benefits from forecasts are captured.

In addition to interest in analysis of rainfall, there has also been interest in the application of seasonal forecast technology to water supplies and irrigation systems. This has led to development of the StreamFlow supplement to Australian Rainman for analysis of streamflow and run-off data (Clarkson *et al*., 2000; Clewett *et al*., 2000a, 2000c, and Clarkson *et al*., 2001). The following is a summary description of the current version of Rainman.

Short description of Australian Rainman

Australian Rainman (Clewett *et al*., 1999) is a comprehensive climate analysis and resource package for farmers, business people, researchers and education. The latest release (version 3.3) is easy to use and innovative in presenting a rich suite of information about Australia's climate and management of climatic risk in three editions: Standard, Educational and Professional. The menus, maps, graphs, tables, text and pictures make the information easy to understand, and the substantive analytical capabilities ensure that it can be used as a powerful research tool.

Australian Rainman is produced on CD ROM and enables people to rapidly evaluate the characteristics of daily, monthly and seasonal rainfall for their location. This includes seasonal forecasts of the amount, timing and frequency of rainfall based on phases and averages of the Southern Oscillation Index (SOI) and Sea Surface Temperatures (SST). There is also information on drought, humidity, temperature and evaporation. Monthly rainfall can be updated each month via the Internet, and users can enter and update rainfall records for their own property. The CD is packaged with a 16-page *"Getting Started"* booklet and includes:

- All of Australia's long-term historical daily and monthly rainfall records from more than 3,870 locations (45 per cent of locations with more 100 years of data,) with scientific details of the data set on the CD from the paper by Owens et al. (1996). (Version 4 of Rainman will also have monthly rainfall data from an additional 9,579 locations throughout the world that have been provided by the National Climate Data Centre, USA. Some 60 per cent of these locations have more than 50 years of good data and 10 per cent have more than 100 years of good data.)
- Analyses of monthly and daily rainfall to characterise the climatology of a location, and to provide drought analyses and seasonal forecasts (amount of rainfall, on-set dates of the wet season, frequency of rainfall events) presented as frequency and time series distributions.
- An interactive multi-media book *Will it Rain?* for understanding the El Nino/Southern Oscillation as the basis of seasonal forecasting and its application to management. While this electronic version has animated diagrams (e.g. of the Walker circulation) to enhance learning processes, a full colour printed version of the book (64 pages) is also available (Partridge, 1994).
- A CD version of the popular Long Paddock Internet site
- A suite of interactive tutorials by George and Brouwer (1999) on managing climate risk and application of seasonal forecast information in the context of agricultural decision-making including several case studies of how farmers and business people are using climate information in their management.
- A library of resource information including: a suite of ready-to-use diagrams that are suited to teaching principles about issues such as the mechanism of ENSO and climate risk management, a list of 80 scientific references for further reading and several scientific papers about Rainman and the data (Clewett *et al*., 1993, 1996 and Owens *et al*., 1996).

Participative processes involved in development

The need to develop and release the original Rainman decision support software package (Clarkson *et al*., 1991), and to produce the book *Will It Rain?* (Partridge, 1991) arose from:

- recognition of climatic risk as a major factor influencing decision-making in rural industries, coupled with the lack of easy access by the rural community in the 1980s to climate data upon which risk management strategies could be developed
- the enthusiastic interest shown by farmers and pastoralists at field-days in the late 1980s to climate data and analyses of seasonal rainfall for their own location. (The risk analyses on seasonal rainfall with durations of 1 to 12 months were pertinent to decision-making and were made available via modem connection to a program called CLIMATE (Willcocks and Lloyd 1988) held on central main frame computer run by the Queensland Department of Primary Industries.)
- severe drought in Central Queensland during the 1982/83 and 1986/87 El Nino events followed by the 1988/89 La Nina
- the influential work of key scientists in Australia during the mid 1980s (especially Dr Neville Nicholls, Dr Greg McKeon and Dr Graeme Hammer) and pivotal publications such as McBride and Nicholls (1983), Nicholls (1985, 1986), McKeon et al. (1986, 1990) and Hammer et al. (1991a, 1991b), and the realisation by the author of the powerful opportunities for better management of climatic risk provided by the combination of new advances in: (a) ENSO-based seasonal forecasts, (b) systems analysis methodology, and (c) development of PC computer technology and decision support software (e.g. Clewett et al., 1991a, 1991b).
- the lack of information in an easy-to-understand form describing the El Nino/Southern Oscillation and its effects on both climate and opportunities to improve management decisions
- high levels of interest shown by farmers, business people and agricultural professionals in the Central Highlands region of Queensland at seminars describing the potential of ENSO for seasonal rainfall forecasting (eg Coughlan, 1989 and Clewett *et al*., 1989)
- a decision by industry representatives, researchers and extension staff at a participative problem-solving workshop on the application of ENSO information (Queensland Department Primary Industries, Emerald, 29 Aug 1989) to embark on a range of initiatives to remedy the situation.

The participative processes used to initiate the Rainman package were continued in the production of the package through testing of Beta software, and in the proposal, development and testing stages of Rainman versions 2, 3 and 4. These participative processes involving industry, RD&E organizations and funding bodies have been fundamental to the *"success"* of Rainman. The name "Rainman" was derived by David Gramshaw in December 1989 from the phrase "*rainfall information for better management.* This was in keeping with the focus on management that was also used for other components of the "Beefman" series of decision support software for the beef industry of northern Australia (Ludwig *et al.*, 1993).

Effective networks of people and organizations were formed in the early stages of developing the proposal for Rainman version 2 to achieve ownership and sense of purpose. Importantly the network included users such as primary producers and agribusiness people and scientists from the Queensland Department of Primary Industries (and now the Dept of Natural Resources and Mines), the Bureau of Meteorology, the West Australian and other State Departments of Agriculture, universities and CSIRO. This was achieved through the development of formal partnerships in both the R&D implementation phase and the marketing phase, and by the direct contribution of people from other organizations in the project proposal for version 2 in January 1992, and their further participation in two workshops in Melbourne to: (a) review use of seasonal forecasting tools, and (b) decide the content of the Rainman package (Clewett, 1995b). The above network has been maintained through the development and application of Rainman version 3 and expanded on an international basis for development of version 4 through the current ACIAR-funded project "*Capturing the benefits of seasonal climate forecasts in agricultural management*". The several funding organizations as described in the acknowledgements have played a key role as part of the participative process for achieving success with Rainman in terms of the wider goal of better management of climatic risk.

Presentation of results

People as individuals have different needs and learning styles, and thus respond to information in different ways. For example, in communicating knowledge of risk we have found that cumulative probability distributions provide an effective mechanism for scientists to communicate with each other. However, in communicating with the farming community we have found that other diagrams and ways of expressing risk are more effective such as frequency plots, pie charts, box plots and time series. The simplest statement for communicating risk has been the percent chance that seasonal rainfall will be above or below the median rainfall (or above or below the average) (Stone *et al*., 1996). While this very simple statement of risk is now widely used in the agricultural media in Australia, the research by Coventry (2001) shows that this statement can be easily misinterpreted by some people because of confusion about probability issues and thus on-going education processes are needed.

The next level for communicating risk is to consider the chance that seasonal rainfall will be: above average (highest 30 per cent), about average, or below average (lowest 30%). The Bureau of Meteorology has used this tercile method in their seasonal forecasts for many years and it is implemented in Rainman as pie charts which can clearly and rapidly show shifts in the chances of rain.

The fullest understanding of climate risk often occurs where people have been able to view all of the historical rainfall (eg. 100 years of data) as a time-series histogram. Time series can be particularly useful because they give an analogue representation of people's chronological memory patterns. Research (Coventry, 2001) has shown that people are more able to assimilate statements about frequency (eg. 7 years in 10) than the more abstract probability statement (eg. 70 per cent chance). Understanding is maximised where different colours are assigned to different year types (such as using red bars for El Nino year types and blue bars in the histogram for La Nina year types). Such a diagram clearly shows the relative frequency and spatial separation of El Nino and La Nina events. The time-series analogue also shows how often above and below median (or above and below average) rainfall occurs without recourse to frequency distribution data or abstract mathematical/statistical representations. Simplicity is often the key to comprehension. Comprehension empowers people with ownership of the forecast and thus confidence in moving towards using it in their decision-making. Technical aspects of the seasonal forecast analyses are given in the following sections.

Scientific basis of seasonal forecast methods used in Rainman

The two main seasonal forecast tools used in Rainman are the Southern Oscillation Index (SOI) and an index of Sea Surface Temperature (SST). The historical values of the SOI (1876 to present) are based on the work of Troup (1965) and Allan *et al.* (1996) and represent standard deviations (times 10) of differences in air pressure anomalies between the central Pacific (Tahiti) and Indonesian region (Darwin). The SOI is provided by the Bureau of Meteorology and is updated and periodically revised on their website. The SST index is also provided by the Bureau and is based on the work of the Bureau of Meteorology Research Centre as described below.

The seasonal forecast analysis method in Rainman version 1 was based on established relationships derived and substantiated from the work of McBride and Nicholls (1983), Nicholls (1984a, 1984b, 1986, 1991), Allan (1988), Ropelewski and Halpert (1987, 1989), Clewett *et al.* (1989, 1991b), Hastings (1990), Drosdowsky and Williams (1991). The evidence in these studies showed strong statistical relationships between seasonal values of the SOI (typically averaged over 3 months) and rainfall in eastern Australia and other parts of the world. Analysis of ENSO impacts on user-defined rainfall seasons in Rainman version 1 were confined to assessing historical rainfall data using the average seasonal (3 month) SOI as the predictor with zero lead-time. Analyses of rainfall data (typically 70 years or more) at a location of the user's choice were presented in tables as frequency and time-series distributions for 3 classes of the SOI using the method of Clewett *et al.* (1989, 1991b). The class boundaries defaulted to: negative (below -5), neutral (-5 to +5), and positive (above +5) for normally distributed data such as monthly values of the SOI, this gives approximately equal values of the monthly SOI in each class. These boundaries were user-adjustable to enable assessment of changes in risk at extreme values of the SOI in a way that is comparable to examining extreme values in regression analyses such as that used at the time by the Bureau of Meteorology (NCC 1991, Nicholls, 1991). Others have also found it useful to examine the extremes of the Southern Oscillation (Hastings 1990, White 2000). Separation of the historical data into several classes and plotting resulting frequency distributions was a relatively new approach in communications that enabled users to rapidly and easily compare likely outcomes from different seasonal forecast scenarios.

The workshop to review the seasonal forecast analyses in Rainman was convened by the National Climate Centre, Bureau of Meteorology in March 1993 and was attended by climatologists (from the Bureau, universities and CSIRO), industry representatives and agricultural scientists from state and national organizations. This provided a rigorous peer review (Clewett, 1995b) of the data and analytical methods published in Rainman version 1 (Clarkson and Owens, 1991). The 2-day review was thorough and concluded that Rainman version 2 (Clewett *et al.*, 1994) should expand the geographic coverage of the rainfall data set to all locations in Australia, expand the analytical and presentation methods used, and develop a national marketing plan. The review concluded that the analyses described above for Rainman version 1 should be retained and expanded to include:

- variable lead time and duration of the SOI predictor
- trends in the SOI
- use of the SST as a predictor
- "break of season" analyses using daily rainfall data

The reasons for these conclusions are described below. Other predictors such as sea level (Mitchell, 1994) and persistence of north-west cloud bands were to be excluded until clear methodologies were resolved. Other analyses such as the 40-day wave were considered to have too many unresolved issues for inclusion. Further development of drought analyses were recommended as were analyses of temperature data, including frost.

Lead-time in Rainman is defined as the gap in time between the end of the predictor period and the start of the rainfall period that is forecast (i.e. the predictand). Several studies highlight the considerable value and need for longer lead-time forecasts for decision making (e.g. Nicholls, 1986; Stafford-Smith, 1998; Ash *et al.*, 2000, Everingham *et al.*, 2002 and Park *et al.*, 2002). Hartman *et al.* (2002) report the legitimate criticisms of resource managers and decision makers of seasonal forecast information that do not target the needs of users. Inclusion of variable lead time as an integral part of the seasonal forecast capability in Rainman versions 2 and 3 is based on:

(a) the need to target as early as possible the rainfall season that is relevant to the decision-making need of the user
(b) conclusions of the 1993 review of Rainman version 1 described above.
(c) findings that the mechanism of the southern oscillation supports longer lead-time forecasts particularly during southern hemisphere winter/spring/early summer period (McBride and Nicholls, 1983; Allan, 1988; Allan *et al*., 1996; Drosdowsky and Williams, 1991; Simmonds and Hope, 1997; and Stone and de Hoedt, 2000).

Use of variable lead-times using the SOI and SST is well established in the literature and variable lead-time analyses have been used in several seasonal forecast analyses (Nicholls, 1985; Nicholls, 1986; Allan, 1988; and Ropelewski and Halpert, 1989; Drosdowsky and Chambers, 2001; and Everingham *et al*., 2002). In assessing use of seasonal forecasts for land, pasture and animal production in Northern Australia, McKeon et al (2000) and Ash et al (2000) conclude that the key component was the need for long-lead forecasts (e.g. a June forecast for the November - March season).

The studies by McBride and Nicholls (1983), Allan (1988) and others reported above also document the value of concurrent or simultaneous analyses for understanding the relationships that have occurred in history between the predictor and the predictand. Users of Rainman are encouraged as part of the philosophy on application of decision support software (Stuth and Lyons, 1991) to explore concurrent and longer lead-time relationships to achieve understanding and an appreciation of the strengths, weaknesses and uncertainties in seasonal climate forecasts. When first investigating relationships for a location or season, it is often best to begin with a concurrent analysis before investigating the strengths and weaknesses of the forecast analysis.

The recommendation of the 1993 peer review to include the trend in the SOI as a seasonal forecast tool was achieved by implementing the SOI Phase system (Stone and Auliciems, 1992 and Stone *et al.*, 1997) in version 2 and it is now used in versions 3 and 4 with zero lead-time as the default forecast method. The SOI Phase system was derived from cluster analysis which revealed 5 phases as follows: 3 phases describing the state of the SOI (positive, neutral and negative), and 2 phases describing the change in the SOI (rapidly Rising and Falling phases). The SOI 5 Phase system is based on just two values of the monthly average SOI (eg. this month, and last month) and can thus respond quickly to changing SOI conditions. The rapid response of the SOI Phase can, in some circumstances, cause instability in the seasonal forecast (e.g. July 2001 to March 2002) however, the rapid response of the SOI is an advantage in the southern hemisphere autumn (April-May) because the rise or fall in the SOI can be a useful indicator of developing El Nino and La Nina conditions and this can be used to advantage in winter cropping decisions (Hammer *et al.*, 1996 and Carberry *et al.*, 2000).

Seasonal forecasts with Indian Ocean SST anomalies with variable lead time were included in versions 2 and 3 based on the research of Drosdowsky (1993c), and importantly, the consensus of scientific opinion at the Melbourne peer review in 1993. It is now proposed that this SST system derived by Drosdowsky (1993c) be upgraded in version 4 with the SST 9 Phase system of Drosdowsky (2002). This is similar to the SST-based operational forecast system now used by the Bureau of Meteorology (Grant Beard, National Climate Centre pers. comm.) and is based on the research of Drosdowsky and Chambers (2001). The SST 9 Phase system is slightly simpler than the Bureau's operational system and is a factorial of 3 Pacific Ocean phases (cool, neutral, warm) by 3 Indian Ocean phases (cool, neutral, warm) calculated from EOFs. To enhance understanding of Pacific Ocean and Indian Ocean relationships with rainfall, the Rainman version 4 prototype enables the Indian and Pacific Ocean main effects to be calculated separately or combined as the 9 phases.

Seasonal forecasts of the "*Break of Season*" as recommended by the 1993 review were implemented in Rainman version 2 as several new analyses to assess the timing, frequency and amount of rain in user-defined rainfall events, and were then upgraded in version 3 to assess the effects of ENSO has on these characteristics. A rainfall event is defined in these analyses by some minimum amount of rain occurring within a maximum period of time (eg. at least 50 mm of rain falling within a 7-day period). The analyses require daily rainfall data and were developed by the Agriculture Department in Western Australia to assess opportunities to better manage wheat production. Through collaborative agreements with Dr Doug Abrecht the West Australia daily rainfall analysis software was adapted for use within Rainman version 2 and then upgraded later for version 3.

Upgraded analyses were developed in Rainman version 3 to assess the influence of ENSO on the characteristics of rainfall events within a season and were: date of first event, date of second event, number of events, and amount of effective rain. These analyses are useful to define the date of on-set of the wet season (Nicholls, 1984c), the chance of follow-up rainfall (Park *et al.*, 2001), and the substantial influence of ENSO on these and other characteristics of rainfall such as *when* and *how often* planting rains for cropping might occur in a season (Nicholls and Kariko, 1993). The analyses can also be used to assess the likelihood of large-scale flooding events as might be associated with the effects of ENSO on tropical cyclonic activity (Nicholls, 1984b, 1992; Hastings, 1990; and Evans and Allan, 1992).

Tests on seasonal forecast skill

Rainman analyses follow accepted scientific conventions by applying several statistical tests to seasonal forecasts so that: (a) users have some guidance regarding the statistical reliability of the forecast information, and (b) there is duty of care in providing forecasts information to users. While this latter point is of value to professional advisors and organizations in terms of risk management, the review of statistical tests in seasonal forecast analyses by Nicholls (2001) clearly shows that there are several significant deficiencies in null hypothesis statistical test procedures and thus complete reliance or over-emphasis on these tests should be avoided. As Rainman is a decision support package, the forecast skill tests are also seeking to minimise risks associated with artificial skill and this is dealt with in more detail later.

The statistical tests used in Rainman are: (1) the Kruskal-Wallis (KW) test as used by Stone and Auliciems (1992), the Kolmogorov-Smirnov (KS) test as described by Conover (1971) for comparing two probability distributions, and (3) the LEPS (Linear Error in Probability Space) skill score test as proposed by Ward and Folland (1990). The non-parametric KW and KS tests are used in preference to Analysis of Variance F tests because rainfall data is often skewed. These tests are calculated using the methods of Conover (1971) and are applied as follows:

- the KW probability is calculated for the 'all years data' but not for each SOI/SST group.
- the KS probability is calculated for each SOI/SST group but not the 'all years' data

The KW test is given precedence over the KS test and in the prototype for version 4 results are *"greyed out"* if they are not statistically significant (threshold value used for KS and KW test values is 0.90). If the KW test is less than 0.90, it is recommended that the long-term climatology (i.e. the data in the 'all years' column) be used to assess climate risks. In calculating the KS test values, the cumulative probability distribution of each SOI (or SST) group is compared against the combined cumulative probability distribution formed from the pooled data in all other groups. For example, the KS test for the SOI negative phase compares the probability distribution for the SOI negative phase against the probability distribution formed from the combined data from the positive, falling, rising and neutral phases. Further details on the KS and KW tests are given in the Rainman *"Help"* notes.

To further assist users to identify seasonal forecast information that is skilful and not just due to chance relationships in the historical data, Rainman version 4 also provides cross-validated LEPS (Linear Error in Probability Space) skill score tests (Ward and Folland, 1990; and Wilks, 1996). The "continuous" method based on equation 12 of Potts *et al.* (1996) is used for calculating the skill score with results presented as tables, graphs and maps. The mapping capabilities of the Rainman version 4 prototype enable comparison of cross-validated skill scores at multiple locations. A significance level for the "continuous" LEPS skill score was identified using a random forecast method similar to that of Drosdowsky and Chambers (2001). A LEPS Skill Score of 7.0 equated with the 0.90 KW test value for these forecasts and the upper 15th percentile of 26,000 random forecasts.

Peer review and adoption

The purpose of this section in the Rainman case study is to highlight the importance of peer review as a necessary part of the quality assurance process in developing decision support systems. In addition to the 1993 Melbourne review, Rainman has been peer-reviewed on many occasions from different perspectives (science, decision-support, communication, education, marketing). Rainman has been presented for review at major International and national conferences (Clewett *et al*., 1993; Clewett, 1995b; Clewett *et al.*, 1996; and George *et al.*, 2000) and this has included independent review processes (White and Stynes 1996, Power *et al.* 2001). The papers by Clewett *et al.* 1993 and 1996 are reproduced in full in Rainman version 3. Examples of external and independent peer reviews are as follows.

- Three separate funding bodies have reviewed previously published versions of Rainman from scientific and decision support perspectives and found in favour of further R&D support on five separate occasions, and on two of those occasions external reviews were commissioned by the funding organization.
- Rainman has been independently reviewed by climatologists and agricultural scientists in several major RD&E organizations in Australia and has been: (a) cleared for purchase of a site licence, (b) adopted as an accredited package for training staff (eg. Bureau of Meteorology Training Centre, South Australia Dept of Agriculture, NSW Agriculture), and (c) adopted for use in research and extension by professional staff.
- Education institutions including universities, schools, agricultural colleges and geography professionals have reviewed Rainman and recommended and/or adopted it for use in teaching programmes (eg. for the courses Weather and Climate in Farming (Bayley, 2000) and Developing climate risk management strategies (ANTA, 2000)).
- Farm journals have given it four and half star ratings as a decision-support package (eg. Buckley, 2000) and national software competitions have awarded honours to Rainman on several occasions for excellence (eg. First prizes at The Australian Farm

Software Competition in 1992 and 1995, and the Asia Pacific Information Technology and Telecommunications software competition in 2000).

- Most importantly some thousands of people have reviewed the overall value of Rainman to their situation and have demonstrated their support by purchasing a copy.

Continuing quality assurance processes and peer review in the development of Rainman version 4 have recently raised several questions concerning artificial skill and multiplicity in the seasonal forecast analyses and have precipitated several improvements. Nicholls (1991) defined multiplicity as *"the statistical problem that arises when a large number of statistical hypotheses are tested (e.g. when many cross correlations are calculated)"* and the effect of multiplicity as *"the probability of incorrectly rejecting at least one null hypothesis increases geometrically as more hypotheses are tested"*.

Artificial skill is described by Nicholls (1991) in two ways. Firstly by "the tuning effect of fitting a model in which the parameters need to be estimated from the available data. This will lead to "artificial" skill, which may disappear when the prediction model is used on new, independent data". Use of cross-validation techniques to measure forecast skill as implemented in the Rainman version 4 prototype (described above) is the recommended approach to avoid these artificial skill problems (Drosdowsky and Allan, 2000; and Tashman 2000). The second source of artificial skill described by Nicholls (1991) and by Wilks (1996) is more relevant to dangers in multiple regression techniques where extra and unnecessary predictors are sometimes included in forecast methods. This second source of artificial skill is not an issue for Rainman because multiple predictors in the one forecast equation are not used.

Multiplicity is however an issue that needs to be appropriately addressed. Rainman can calculate several independent forecasts for the one locality because it can apply several predictors (average SOI, SOI Phase and SST Phase) at several lead times at several locations in the one locality. One in 10 of these forecast results can be expected to be *"statistically significant"* just due to chance because the statistical test significance levels are set at 0.90. The occurrence of 1 in 10 statistically significant forecasts due to just chance is also true when forecasts are routinely assessed every month. Thus, there is need to emphasise the value of spatial and temporal coherence in seasonal forecasts to help weed out the occurrence of "rogue" forecasts that are an artefact of the historical data. Multiplicity is an important issue that must be dealt with in an effective way and is done so in the Rainman package by:

- always providing seasonal forecasts as frequency-based information that are derived from historical data, thus the forecast information is never "wrong" and this provides corporate protection
- providing data in a variety of ways that clearly demonstrates the strengths, weaknesses and riskiness of seasonal forecast information
- guiding users through the "Help" and "Tutorial" systems that: (a) identify appropriate methods to approach seasonal forecast analyses, (b) reveal uncertainties about the forecasts in ways that are consistent with the risk management conclusions of Clark and Brinkley (2001), (c) bring attention to the cognitive biases and difficulties that people have in using probabilistic information (Nicholls, 1999; White, 2000; and Coventry, 2001) and (d) encourage users to identify a priori hypotheses concerning the target management decision and thus avoid "engaging in haphazard fishing expeditions which will almost certainly find some statistically significant relationship" (Drosdowsky and Allan, 2000). The prominent "Chance result or Real Skill" red button in the Rainman version 4 prototype draws attention to and displays the following text:

All seasonal analyses in Rainman are based on historical data and thus use of Rainman for forecasts of seasonal rainfall is dependent on the statistical relationships in the historical data. These relationships may be a guide to the future. Statistical tests on the skill of seasonal forecasts are useful because they help to weed out erroneous results in the data, and to reveal where tools such as the Southern Oscillation Index (SOI) and Sea Surface Temperature (SST) have "real" rather than "artificial" skill as indicators of future events. When statistically "not significant" relationships between ENSO indicators and rainfall are observed in the data, then users should reject use of the ENSO indicator for that location/season, and use the all-years climate information for the seasonal forecast. The following practices should be adopted in assessing seasonal forecast analyses from Rainman:

- *firstly define the purpose (e.g. the agricultural decision being made) for using the seasonal analysis information in Rainman, and then use the purpose to define the rainfall season*
- *use climatology (i.e. data in the all-years column) as the primary seasonal forecast method*
- *consider the mechanisms of ENSO (e.g. read Will It Rain ?) and if convinced that there is sound reason for impacts of ENSO on the location and season of choice then proceed to examine relationships of ENSO indicators with seasonal rainfall*
- *examine the statistical significance and variability of relationships (examine data in different ways e.g. use of tables, pie charts, box plots and importantly the historical time-series plots)*
- *examine the reliability of the ENSO signal by examining results for different periods of time (see the historical time-series plots), adjacent seasons and lead-times (use the Period of Skill analysis), neighbouring locations (use the mapping analysis) and different forecast tools (Average SOI, SOI Phases and SST Phases).*

Independent and competing forecasts are common place in meteorology and occur in most other disciplines (finance, commodity and labour markets), and thus dealing with competing and sometimes misleading information is a common circumstance in the every day life of farmers, business people and resource managers. Issues concerning decisions about choosing between forecasts or combining results from several forecasts are examined by Clemen *et al.* (1995); Nicholls (2000); and Armstrong (2001). Rainman does not attempt to deal with these issues. However, there is an emerging view that use of quantitative and objective methods to combine forecasts and thus prepare ensemble forecasts has merit (Armstrong, 2001 and Drosdowsky, 2002).

Some 3000 copies of Rainman and approximately 6300 copies of *Will It Rain?* have been distributed throughout Australia. A further 1500 copies of the Indonesian version of *Will it Rain?* (Partridge and Ma'Shum, 2002) are being distributed through the University of Mataram. The distribution of Rainman includes several hundred copies being used through site licences in 5 major organizations. Many packages are used by groups of people and thus total usage is estimated to be in excess of 10,000 people. Users include: primary producers across a wide range of industries; extension services (government and private consultants); business people from the agricultural, construction, tourism, health, mining and financial sectors; researchers across a variety of disciplines; and educational institutions from secondary, tertiary and vocational fields.

Benefits from the development and application of Rainman

Climate variability has large influences on the sustainability of land use practices and on the profitability of businesses in the food and fibre chain. Better climatic information can lead to better business decisions and land management. Rainman has made a significant contribution to land management practices by providing a high-quality and easily accessible suite of information about climatic risk and the application of seasonal forecasts including several examples as case studies in the tutorials. This enables people to build their knowledge and skills to make better decisions. Examples include: improved choice of crops and fertiliser use; matching stocking rates to expected feed supplies; more efficient use of irrigation water; and smarter financial decisions.

Rainman has raised awareness of climate forecasting as a land management tool and awareness of the Southern Oscillation as a major factor-influencing climate in many parts of the world. There was little knowledge of ENSO in the Australian community when Rainman was first produced in 1991. Since then a marked improvement in climate knowledge and management of climate risk has occurred, and while several major educational campaigns have contributed to this improvement, some significant part is due to the use of Rainman by many people. While quantitative assessment of overall impacts is not possible, there are many anecdotal accounts now available of how climate risk and ENSO information has helped large numbers of people in their business decisions (George *et al*., 2000).

Several factors have contributed to the success of Australian Rainman including:

- Meeting the needs of people by producing a package that is comprehensive, easy to use, locally relevant, and addressing the problems that people face in managing climatic risk by:
    - (a) targeting the required location, season and lead-time
    - (b) providing clear information about risk and whether forecast skill is present or not
    - (c) providing interpretive tutorial processes and materials.
- Seasonal climate forecasts are perceived to be very useful in agricultural management and thus Rainman is seen as useful because it empowers people with the necessary knowledge and skills to apply seasonal forecasting technology to their management decisions.
- The CD technology used enables fast, reliable and comprehensive delivery of information, the computer programming software is at the forefront of technology, the combination of data, analytical capacity, tutorials and reference information give the product balance, and the package mix can grow to take on new information (eg. streamflow and runoff) and new climate forecasting methods as the science improves.
- The marketing and communications program has been effective and the package has been promoted and sold at an affordable price through a range of outlets and with standard, educational, professional and network options to suit different user groups. Gaining national recognition through achieving several prestigious awards in national IT competitions has been an important element of the communications strategy.

Conclusion

The seasonal forecast capabilities of Rainman have been developed from results of soundly based research on the characteristics of ENSO. This development has occurred over quite some time in a truly participative problem-solving framework that has involved collaboration with industry and several organizations.

The Rainman case study shows that software is an effective way to provide people with climatic information because it can be detailed but easy to use, comprehensive and locally relevant. Providing information in different formats is useful because people learn in different ways, however, the most effective method for communicating the risk dimension in seasonal forecasts is with frequency information displayed as the time series distribution.

People gain confidence in probabilistic seasonal forecasts when they understand the physical basis of ENSO and thus the reasons for its influence on global, regional and local climate patterns. The relationships of ENSO with changes in the characteristics of seasonal rainfall (timing, frequency of events and amount) at their own location and consequent impacts on agriculture are important.

Learning to use ENSO information in management is maximised by combining “hands on” learning with the software with participation in a workshop situation where people can test their ideas and also listen to the knowledge and experience of others (Clewett *et al.*, 2000b).

Current research is extending the application of Rainman to other countries including Indonesia, Zimbabwe and India in the collaborative project entitled “ *Capturing the Benefits of Seasonal Climate Forecasts in Agricultural Management”* funded by the Australian Centre for International Agricultural Research.

There is continuing demand from users for a Rainman suite of information on a website.

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References

Allan, R.J., 1988. El Nino Southern Oscillation influences in the Australasian region. Prog. Physical Geograpghy 12: 4-40.

Allan, R.J. and Pariwono, J.I., 1990. Ocean-atmosphere interactions in low-latitude Australasia. Int. Journal of Climatology 10:145-178.

Allan, Rob, Lindsay, J. and Parker, D., 1996. El Nino Southern Oscillation and Climate Variability, Australia: CSIRO.

Allan, R.J., Beard, G., Close, A., Herczeg A.L., Jones, P.D. and Simpson, H.J., 1996. Mean sea level pressure indices of the El Nino-Southern Oscillation: relevance to stream discharge in south-eastern Australia. CSIRO Division of Water Resources Report 96(1).

ANTA, 2000. Developing climate risk management strategies. AG5215 BM Agriculture and Horticulture Vocational Training Package, Canberra: ANTA (Australian National Training Authority).

Armstrong, J.S. (ed), 2001. Principles of Forecasting: A handbook for researchers and practitioners. Kluwer Academic.

Ash, A., O'Reagain, P, McKeon, G.M. and Stafford-Smith, M., 2000. Managing climate variability in grazing enterprises: A case study of Dalrymple Shire, North Eastern Australia. *In* G.L. Hammer, N. Nicholls and C. Mitchell (eds.) Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience, The Netherlands: Kluwer Academic.

Bayley, D., 2000. Weather and Climate in Farming: Managing risk for profit. State of New South Wales, NSW Agriculture.

Brouwer, D. and George, D., 1995. Climate and Your Farm. New South Wales Agriculture Home Study Program, New South Wales Agriculture.

Buckley, D., 2000. Climate Risk – Forecasts help farmers to minimise losses. Farming Ahead Journal, Kondinin, September, 2000.

Carberry, P., Hammer, G.L., Meinke, H. and Bange, M., 2000. The potential value of seasonal climate forecasting in managing cropping systems. *In* G.L. Hammer, N. Nicholls and C. Mitchell (eds). Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience, The Netherlands: Kluwer Academic.

Clark, A.T. and Brinkley, T., 2001. Risk Management: for Climate Agriculture and Policy, Commonwealth of Australia: Bureau of Rural Sciences.

Clarkson, N.M. and Owens, D.T., 1991. RAINMAN - Rainfall Information for Better Management, Brisbane: Queensland Department of Primary Industries, (PC software on disk).

Clarkson, N.M., Clewett, J.F. and Owens, D.T., 2001. STREAMFLOW: a supplement to Australian Rainman to improve management of climatic impacts on water resources, Toowoomba: Queensland Government, Department of Primary Industries, (a PC software package on CD ROM).

Clarkson, N.M., Owens, D.T., James, R.A. and Chiew, F.H.S., 2000. Seasonal streamflow forecasts to improve management of water resources 3. Issues in assembling an adequate set of Australian historical streamflow data for forecasting. Proceedings of the 26th National and 3rd International Hydrology and Water Resources Symposium of The Institution of Engineers, 20-23 November 2000, Perth, Australia.

Clemen, R.T., Murphy, A.H. and Winkler, R.L., 1995. Screening probability forecasts: contrasts between choosing and combining. International Journal of Forecasting 11:133-146.

Clewett, J.F., Taylor, W.J., McKeon, G.M., Neal, J.A., Howden, S.M., Young, P.D., Rickert, K.G. and Wilson, R., 1988a. BEEFMAN: Computer systems for evaluating management options for beef cattle in northern Australia. Proceedings Australian Society Animal Production 17:367.

Clewett, J.F., Young, P.D. and Willcocks, J.R., 1989. Effect of climate change on agriculture in central Queensland: rainfall variability analysis. *In* E.R. Anderson (ed.). The changing climate and central Queensland Agriculture, Rockhampton: Australian Institute of Agricultural Science.

Clewett, J.F., Cavaye, J.M., McKeon, G.M., Partridge, I.J. and Scanlan, J.C., 1991a. Decision support software as an aid to managing pasture. Tropical Grasslands 25: 159-164.

Clewett, J.F., Howden, S.M., McKeon, G.M. and Rose, C.W., 1991b. Optimising farm dam irrigation in response to climatic risk. *In* R.C. Muchow and J.A. Bellamy (eds.) Climatic Risk in Crop Production: Models and Management for the Semi-arid Tropics and Subtropics, Wallingford, U.K.: CAB International.

Clewett, J.F., Clarkson, N.M., Owens, D.T. and Partridge, I.J., 1993. Rainman: Using El Nina and Australia's rainfall history for better management today. *In* S. Field (ed.), Harnessing Information for a Smarter Agriculture, Proceedings of the Australian Institute of Agricultural Science National Conference, Launceston, September 1992.

Clewett, J.F., Clarkson, N.M, Owens, D.T. and Abrecht, D.G., 1994. Australian Rainman: Rainfall Information for Better Management, Brisbane: Department of Primary Industries (PC software on disk).

Clewett, J.F., 1995a. Australian Rainman: A computer package for better decision-making. Proceedings of International Conference "Tropical Oceans Global Atmosphere", Melbourne: Bureau of Meteorology.

Clewett, J.F., 1995b. Review of Climate Prediction Tools. Proceedings from Rainman review workshop, National Climate Centre, Melbourne, 18-19 March 1993. *In* Final report on Project DAQ 141A "Rainman: Rainfall Information for Rural Communities" to Rural Industries Research and Development Corporation, 26 April 1995, Brisbane: Qld Dept Primary Industries.

Clewett, J.F., Clarkson, N.M., Partridge, I.J., and Abrecht, D.G., 1996. Australian Rainman: Progress and Prospects. *In* Proceedings of Managing with Climatic Variability Conference '*Of droughts and flooding rains*', 16-17 November 1995. Land and Water Resources Research and Development Corporation, Canberra. Occasional Paper CN03/96.

Clewett, J.F., Smith, P.G., Partridge, I.J., George, D.A. and Peacock, A., 1999. Australian Rainman Version 3: An integrated software package of Rainfall Information for Better Management, QI98071, Queensland: Department of Primary Industries (PC software on CD).

Clewett, J.F., Clarkson N.M. and Chiew, F.H.S., 2000a. Seasonal streamflow forecasts to improve management of water resources 2. Impact of climate variability and ENSO on streamflow and runoff in Australia. Proceedings of the 26th National and 3rd International Hydrology and Water Resources Symposium of the Institution of Engineers, 20-23 November 2000, Perth, Australia.

Clewett, J., George, D., Cliffe, J., Drosdowsky, W., O'Sullivan, D., Paull, C., Partridge, I., and Saal, R., 2000b. Building Knowledge and Skills to use Seasonal Climate Forecasts in Property Management Planning. *In* G.L. Hammer, N. Nicholls and C. Mitchell. (eds.) Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience", The Netherlands: Kluwer Academic.

Clewett, J.F., Thompson, P.J.M., George, D.A., Owens D.T., and Clarkson. N.M., 2000c. Seasonal streamflow forecasts to improve management of water resources: 4. Communicating results to improve knowledge and skills of clients in Australia. Proceedings of the 26th National and 3rd International Hydrology and Water Resources Symposium of the Institution of Engineers, 20-23 November 2000, Perth, Australia.

Cobon, D., and Clewett, J.F., 1999. DroughtPlan CD: a compilation of software packages, workshops, case studies and reports to assist management of climate variability in pastoral areas of northern Australia. Information Series QI99002, Brisbane: Queensland Department of Primary Industries.

Conover, W.J., 1971. Practical Non-Parametric Statistics. John Wiley and Sons.

Coughlan, M., 1989. *In*. E.R. Anderson (ed.) The changing climate and central Queensland Agriculture, Rockhampton: Australian Institute of Agricultural Science,

Coventry, W., 2001. Climate variability and farmers risk assessments and decision making. Post-graduate thesis, School of Psychology, University of Queensland

Drosdowsky, W., 1993a. An analysis of Australian seasonal rainfall anomalies: 1950-1987. I: Spatial patterns. Int. Journal Climatology

Drosdowsky, W., 1993b. An analysis of Australian seasonal rainfall anomalies 1950-1987. II: Temporal variability and teleconnection patterns. Int Journal Climatology 13:111-149.

Drosdowsky, W., 1993c. Potential predictability of winter rainfall over southern and eastern Australia using Indian Ocean sea-surface temperature anomalies. Aust Meteorologgy Magazine 42:1-6.

Drosdowsky, W., 1996. Variability of the Australian summer monsoon at Darwin: 1957-1992. Journal of Climate 9:85-96

Drosdowsky, W. and Williams, M., 1991. The southern oscillation in the Australian region. Part I: Anomalies at the extremes of the oscillation. Journal of Climate 4:619-638.

Drosdowsky, W., 2002. SST Phases and Australian Rainfall. Aust. Met. Mag. 51(1): 1-12.

Drosdowsky, W. and Allan, R., 2000. The potential for improved statistical seasonal climate forecasts. *In* G.L. Hammer, N. Nicholls and C. Mitchell (eds.) Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience, The Netherlands: Kluwer Academic.

Drosdowsky, W. and Chambers, L.E., 2001. Near-global sea surface temperature anomalies as predictors of Australian seasonal rainfall. Journal of Climate 14:1677-1687.

Evans, J.L. and Allan, R.J., 1992. El Nino/Southern O scillation modification to the structure of the monsoon and tropical cyclone activity in the Australasian region. Int. Journal of Climatology 12:611-623.

Everingham, Y.L., Muchow, R.C., Stone, R.C., Inman-Bamber, N.G., Singels, A. and Bezuidenhout, C.N., 2002. Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. Agricultural Systems 74(3):459-477.

George, D.A., and Brouwer, D., 1999. Tutorials. *In* J.F. Clewett, P.G. Smith, I.J. Partridge, D.A. George, and A. Peacock, 1999. Australian Rainman Version 3: An integrated software package of Rainfall Information for Better Management, Brisbane: Queensland Department of Primary Industries.

George, D., Cobon, D., and Bayley, D., 1999. Developing Climate Education and Agriculture in Australia: Australian “Rainman”, “DroughtPlan”, and other educational resources. International Conference “Education: Weather, Ocean, Climate”, Aust. Met. and Oceanographic Society, 5 –9 July, 1999, Ballarat and Melbourne, Australia.

George, D., Clewett, J.F., McBride, J., Balusubramanian, T.N., Huda, A.K.S., Geethalakshmi, V., Selvaraju, R. and Mavi, H., 2000. Seasonal climate and weather forecasting: agricultural applications. *In* Managing Natural Resources for Sustainable Agricultural Production in the 21st Century, International. Conf. Proc., 14-18 Feb 2000, New Delhi: Indian Council of Agricultural Research.

George, D.A. and Selvaraju, R.N., 2002. Building knowledge and skills to apply seasonal climate forecasts in agriculture. *In* Applying seasonal climate forecasts in agriculture. Conference Proceedings, Tamil Nadu Agricultural University, India, 24-26 September 2002 (in press).

Halpert, M.S. and Ropelewski, C.F., 1992. Surface Temperature Patterns Associated with the Southern Oscillation. Journal of Climate 5:577-593.

Hammer, G.L. and Muchow, R., 1991a. Quantifying climatic risk to sorghum in Australia’s semi-arid tropics and sub-tropics: model development and simulation. *In* R.C. Muchow and J.A. Bellamy (eds.) Climatic Risk in Crop Production: Models and Management for the Semi-arid Tropics and Subtropics’, Wallingford, U.K.: CAB International.

Hammer. G.L., McKeon, G.M., Clewett, J.F. and Woodruff, D.R., 1991b. Usefulness of seasonal climate forecasts in crop and pasture management. Proceedings of First Australian Conference on Agricultural Meteorology, Bureau of Meteorology, Melbourne. .

Hammer, G.L., Holzworth, D.P. and Stone, R.C., 1996. The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. Aust. Journal of Agricultural Research 47: 717-737.

Hammer, G.L., 2000. Applying seasonal climate forecasts in agricultural and natural ecosystems – a synthesis. *In* G.L. Hammer, N. Nicholls and C. Mitchell (eds.) Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience, The Netherlands: Kluwer Academic.

Hammer, G.L., Nicholls, N. and Mitchell, C. (eds), 2000. Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience, The Netherlands: Kluwer Academic.

Hammer, G.L., Hansen, J.W., Phillips, J.G., Mjelde, J.W., Hill, H., Love, A., and Potgieter, A., 2001. Advances in application of climate prediction in agriculture. Agric Systems 70:515-553.

Hartmann, H.C., Pagano, T.C., Sorooshian, S. and Bales, R., 2002. Confidence Builders: Evaluating Seasonal Climate Forecasts from User Perspectives. Bulletin of the American Meteorological Society. 83(5):683–698.

Hastings, P.A., 1990. Southern Oscillation Influences on Tropical Cyclone Activity in the Australian/South West Pacific Region. Int. Journal of Climatology 10: 291-298.

Haylock M. and McBride, J., 2001. Spatial coherence and predictability of Indonesian wet season rainfall. Journal of Climate 14:3882-3887.

Ludwig, J.A., Clewett, J.F. and Foran, B.D., 1993. Meeting the needs of decision support software users: Australian rangelands. *In* J.W. Stuth, and B.G. Lyons (eds.). Emerging Issues for Decision Support Systems for Management of Grazing Lands, Paris: Parthenon Publishing Group.

McBride, J.L. and Nicholls, N., 1983. Seasonal relationships between Australian rainfall and the Southern Oscillation. Monthly Weather Review 111:1998-2004.

McKeon, G.M. Rickert, K.G. and Scattini, W.J., 1986. Tropical pastures in the farming system: case studies of modelling integration through simulation. Proceedings of the Third Australian Conference on Tropical Pastures, Occasional Publication No. 3. Tropical Grassland Soc. of Australia.

McKeon, G.M., Day, K.A., Howden, S.M., Mott, J.J., Orr, D.M., Scattini, W.J. and Weston, E.J., 1990. Northern Australian savannas: management for pastoral production. Journal Biogeog. 17: 355-72.

Mielke, P.W., K. J. Berry, C. W. Landsea and W. M. Gray, 1996. Artificial skill and validation in meteorological forecasting. Weather Forecasting 11:153-169.

Mitchell, W.M, 1994. Using mean sea level anomalies as an indicator of regional climate variability. Agr. Sys. Info. Tech. 6:19-21.

NCC, 1991. Seasonal Climate Outlook Service: what it is and how to use it. National Climate Centre, Bureau of Meteorology.

Nelson, R.A., Holzworth, D.P., Hammer, G.L. and Hayman, P.T., 2002. Infusing the use of seasonal climate forecasting into crop management practice in North East Australia using discussion support software, Agric. Systems (submitted Dec 2001).

Nicholls, N., 1984a. The Southern Oscillation and Indonesian sea surface temperature. Monthly Weather Review 112:424-432.

Nicholls, N., 1984b. The Southern Oscillation, sea-surface-temperature, and inter-annual fluctuations in Australian tropical cyclone activity. Journal Climatology 4:661-670.

Nicholls, N., 1984c. A system for predicting the onset of the north Australian wet-season. Journal Climatology 4:425.

Nicholls, N., 1985. Impact of the Southern Oscillation on Australian crops. Journal Climatology 5:553-560.

Nicholls, N., 1986. Use of the Southern Oscillation to predict Australian Sorghum yield. Agricultural and Forest Meteorology 38:9-15.

Nicholls, N., 1989. Sea surface temperature and Australian winter rainfall. Journal Climatology 2:965-973.

Nicholls, N., 1991. Advances in long-term weather forecasting. *In* R.C. Muchow, and J.A. Bellamy (eds.) Climate risk in crop production: models and management for the semiarid tropics and subtropics. CAB International.

Nicholls, N., 1992. Recent performance of a method for forecasting Australian seasonal tropical cyclone activity. Australian Meteorological Magazine 40:105-110.

Nicholls, N., 1995. All-India summer monsoon rainfall and seas surface temperatures around northern Australian and Indonesia. Journal of Climate 8:1463-1467.

Nicholls, N., 1999. Cognitive illusions, heuristics, and climate prediction. Bulletin of the American Meteorological Society 80:1385-1397.

Nicholls, N., 2001. Commentary and analysis: the insignificance of significance testing. Bulletin of the American Meteorological Society 81:981-986.

Nicholls, N. and Kariko, A., 1993. East Australian Rainfall Events: International Variations, Trends, and Relationships with the Southern Oscillation. Journal of Climate 6:1141-1152.

Owens, D.T., Clarkson, N.M. and Flood, N., 1996. Development of a long-term Daily and Monthly Rainfall Collection for Australia. *In* The Impact of Weather and Climate on Agriculture Proceedings of the Second Australian Conference on Agricultural Meteorology, University of Queensland, Brisbane, 1-4 October 1996.

Park, J.N., Cobon, D.H. and Crabb, D.M., 2001. Integrating climate forecasts and geospatial systems to enhance grazing management in northern Australia. *In* Proceedings of Geospatial Conference, Sydney.

Park, J.N., Cobon D.H., Simpson G.B. and Clewett, J.F., 2002. The utility of forecasting summer rainfall and modelled pasture growth in the Mitchell grasslands of western Queensland. Proceedings of Australian Rangelands Society Conference, Kalgoolie, September 2002.

Partridge, I.J. (ed.), 1991. Will It Rain?: El Nino and the Southern Oscillation. Queensland Department of Primary Industries, Brisbane, Information Series QI91028.

Partridge, I.J. (ed.), 1994. Will It Rain? The effects of the Southern Oscillation and El Nino on Australia. Second Edition, Department of Primary Industries Queensland, Brisbane, Information Series QI94015.

Partridge, I. J. and Mansur Ma'shum, 2002a. Will it rain?: The effect of the Southern Oscillation and El Nino in Indonesia, Brisbane: Department of Primary Industries.

Partridge, I. J. and Mansur Ma'shum, 2002b. Kapan hujan turun? Dampak Osilasi Selatan dan El Nino di Indonesia, Brisbane: Department of Primary Industries.

Potts, J.M., Folland, C.K., Jolliffe, I.T. and Sexton, D., 1996. Revised "LEPS" scores for assessing climate model simulations and long-range forecasts. Journal of Climate 9:34-53.

Power, S., Wright, W. and Della Marta, P. (eds.), 2001. Cli-Manage 2000 - Conference on Managing Australian Climate Variability - Climate Variability in Agriculture National Conference Proceedings, 23-25 October 2000, National Climate Centre, Bureau of Meteorology, Melbourne.

Robinson, S. and Abrecht, D., 1993. TACT User Manual. A seasonal wheat sowing decision aid. Program version number 2.0. Western Australian Department of Agriculture.

Ropelewski, C.F. and Halpert, M.S., 1987. Global and regional scale precipitation patterns associated with the El Nino/Southern Oscillation. Monthly Weather Review 115:1606-1626.

Ropelewski, C.F. and Halpert, M.S., 1989. Precipitation patterns associated with the high index phase of the Southern Oscillation. Journal Climatology 2:268-284.

Scanlan, J.C. and McKeon, G.M., 1990. GRASSMAN: a computer program for managing native pastures in eucalypt woodlands, v. 1.0. Queensland Department of Primary Industries, Brisbane.

Simmonds, I. and Hope, P., 1997. Persistence characteristics of Australian rainfall anomalies. Int. Journal of Climatology 17:597-613

Stone, R.C. and de Hoedt, G., 2000. The development and delivery of current seasonal climate forecasting capabilities in Australia. *In* G.L. Hammer, N. Nicholls and C. Mitchell (eds.) Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience, The Netherlands: Kluwer Academic.

Stone, R.C. and Auliciems, A., 1992. SOI phase relationships with rainfall in eastern Australia. International Journal of Climatology 12:625-636.

Stone, R.C., Hammer, G.L. and Marcussen, T., 1996. Prediction of global rainfall probabilities using phases of the southern oscillation index. Nature 384:1896-1909.

Stafford-Smith, M., Clewett, J.F., Moore, A.D., McKeon, G.M. and Clark, R., 1998. DroughtPlan – building on grazier participation to manage climate variability. Land and Water Resources Research and Development Corporation, Canberra. Occasional Paper CV01/97, Canberra.

Stuth, J.W. and Lyons, B.G. (eds.), 1993. Decision Support Systems for the Management of Grazing Lands. Man and the Biosphere Series 11, Paris: The Parthenon Publishing Group.

Tashman, L.J., 2000. Out-of-sample tests of forecasting accuracy: an analysis and review. Int Journal of Forecasting 16:437-450.

Troup, A.J., 1965. The Southern Oscillation. Quart. Journal of the Royal Meteorology Society 91:490-506.

Ward, M.N. and Folland, C.K., 1990. Prediction of seasonal rainfall in the north nodeste of Brazil using eigenvectors of sea-surface temperature. International Journal of Climatology 11:711-743.

White, B.J., 2000. The importance of climate variability and seasonal forecasting to the Australian economy. *In* G.L. Hammer, N. Nicholls and C. Mitchell (eds) Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – the Australian Experience, The Netherlands: Kluwer Academic.

White, B.J. and Stynes, B., 1996. In panel discussion of R&D priorities, Proceedings of Managing with Climatic Variability Conference 'Of droughts and flooding rains', 16-17 November 1995. Land and Water Resources Research and Development Corporation, Canberra. Occasional Paper CN03/96.

Wilks, D.S., 1996. Statistical methods in the atmospheric sciences. International Geophysics Series 59. Academic Press.

Willcocks, J.R. and Lloyd, P.L., 1988. The QDPI's Climate Data Bank. *In* Australia's Rangelands'. Australian Rangeland Society Conference Proceedings, Longreach, June 1988.

Woodruff, D.R., 1992. Wheatman a decision support system for wheat management in subtropical Australia. Aust. Journal Agric. Res. 43:1483-1499.

Early Warning System against Cool Summer Damage: Case of Northern Japan

Masaharu Yajima[*]

Introduction

Rice yield has been increased tremendously by the development of improved nursery techniques, new varieties resistant to lodging and diseases, and new yield-enhancing agrochemicals. Although high rice yields are commonly attained by the rice farmers, yield fluctuations sometimes occur due to unfavorable weather conditions during the rice cropping season in particular areas. For instance, severe spikelet sterility due to cool weather that occurred during the meiosis to flowering stage of the rice crop in some areas of Tohoku District in 1980, 1989 and 1993, greatly reduced yield. The severity of spikelet sterility, due to cool weather, is an alarming situation that needs attention through redirection of research focus to varietial improvement, improvement of cultivation techniques and/or evasion of the damage.

As an initial response to the problem, a quantitative technique to monitor crop growth and development was developed based on real time climatic data. In such cases, crop and weather information could be provided to the farmers for the possible reduction or avoidance of spikelet sterility due to cool weather knowing the agronomic characteristics of the cultivar they will plant.

This paper intends to describe the research approach and present initial results of wide area monitoring of crop growth and development using a rice crop model and introduce the current version of "Climatic Early Warning System against cool summer damage" by the National Agricultural Research Center for the Tohoku Region.

Monitoring crop growth and development using a rice crop model

Crop models

The approach involved the use of the development stage, spikelet sterility yield models and crop and geo-climatic data sets for the development of the prediction system.

Development stage model for rice

Based on the development stage (DVS) model designed by Prof. T. Horie (1987), values of 0, 1, and 2 are assigned to emergence (seed germination), heading and physiological maturity, respectively. The value of DVS at any point of crop development is calculated by integrating the developmental rate (DVR) with time:

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$$DVS\ (t) = \Sigma\ DVR\ i\ , \qquad (1)$$

where: DVS(t) is the developmental stage on the ith day, and DVR i is the development rate on the ith day from emergence. Horie and Nakagawa (1990), suggested that DVR, from emergence to heading of rice plant, could be expressed as a function of daylength (L) and daily mean temperature (T) such as:

$$DVR = 1/G * [1 - exp\ \{B(L - Lc)\}] / [1 - exp\{ -A\ (T - Th)\}], \qquad (2)$$

or

$$DVR = a\ (T - To), \qquad (3)$$

Where, Lc, T h, To, A and B are parameters (coefficients).

Equation 3 is used when transplanting dates are fixed and when rice varieties planted are non or weakly photosensitive. This equation is only applicable when DVR increases linearly with the temperature.

Dry matter accumulation

Generally, dry matter accumulation at any point of rice growth is proportional to accumulated solar radiation intercepted by the canopy, except at the final stage of rice growth when DVS is close to 2. The model used to estimate daily dry matter increase was adopted from Monteith (1977):

$$dW / dt = K_1(N) * S_0\ exp\ \{ 1 - (K_2 * F)\} \qquad (4)$$

where: dW/dt is the daily change in dry weight ($g/m^2/day$); $K_1(N)$ is the radiation-use efficiency ($g/\ m^2/MJ$); and F is the leaf area index (LAI). To generate LAI in eq.(4), the following model was modified as a function of basal fertilizer application, which is based on SIMRIW by Horie (1987).

$$dF/dt = R_m(N)\ [\ 1- exp\{ - K_f(N)(T-T_0)\}]*[\{1- (F/F_a(N))^n\}F] \qquad (5)$$
$$dF/dt = 0\ for\ T< T_0\ and\ dF/dt = -.01 * LAI_{max} * DVS$$

where: dF/dt is the daily change in LAI. $R_m(N)$, $K_f(N)$, $F_a(N)$ are parameters depending on the amount of nitrogen (N) application. LAI_{max} is LAI at heading.

After heading, it was assumed that $K_1(N)$ is reduced to .7 of its value used before heading.

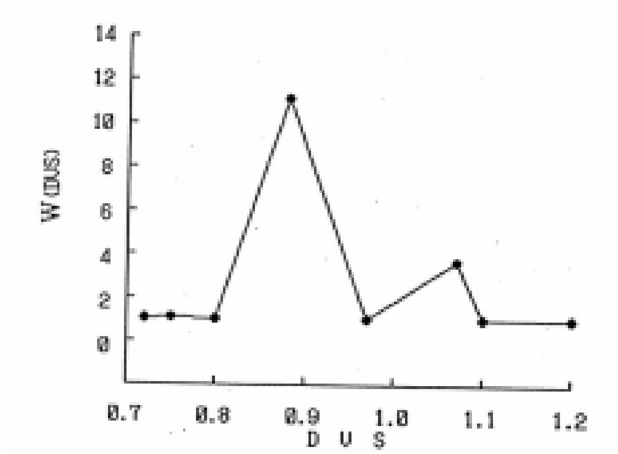
Spikelet sterility model for rice

The spikelet sterility model on the relationship between spikelet sterility and cool temperature sensitivity of rice plants at the panicle development stage was proposed by Yajima *et al*. (1989), with the following equation:

$$G = \bullet\ (To - Ti)\ W(DVS)$$
$$for\ Ti < 18.9\ and,\ 1.20 > DVS > 0.72 \qquad (6)$$

Where, W(DVS) is the panicle sensitivity factor to cool temperature as a function of DVS. The value of W was based on the spikelet sterility data obtained by using the var. Sasanishiki in Miyagi Prefecture (1988). Rice shows two sensitivity peaks to cool temperatures. The first is observed at DVS = 0.88 which corresponds to the meiosis of the pollen mother cell, and the second is at DVS = 1.07 which corresponds to the mid-flowering stage (Figure 1).

Figure 1. Effect of cool temperature on sensitivity to spikelet sterility



Source: Yajima, *et al.*, 1994.

Yield

Grain yield is proportional to dry matter accumulation at physiological maturity (W_m) and expressed as follows:

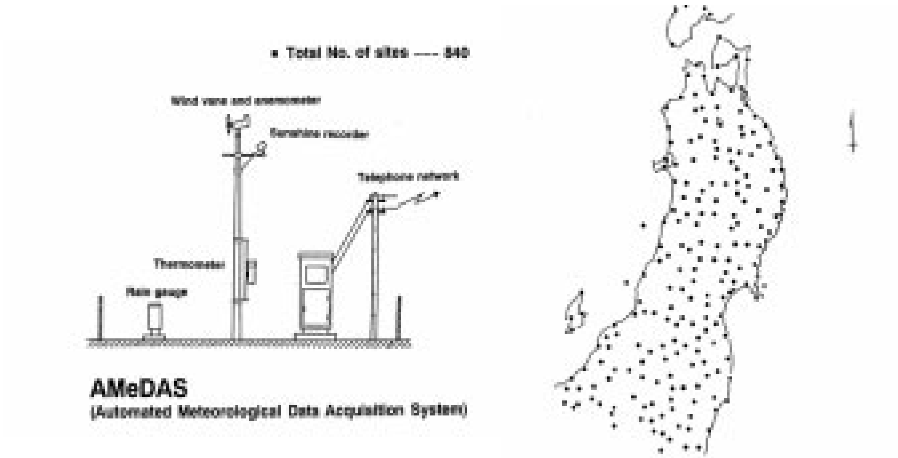
$$Y = HI * (1 - UF/100) * W_m \qquad (7)$$

Where, Y is the grain yield (brown rice) and HI is harvest index with a value of 0.4.

Crop and weather data

Crop data such as, variety planted, transplanting date, heading date and actual paddy yield were provided by the Dept. of Statistics, Ministry of Agriculture, Forestry and Fisheries (MAFF). Meteorological data such as air temperature, has been collected from 860 sites all over Japan since 1974. The Automated Meteorological Data Acquisition System (AMeDAS), provided the real-time weather information throughout Japan. The Geographic Information System (GIS) in Japan also provided the information on land elevation, land use, and other geographical data for each rectangular grid-point, 1 km x 1 km in dimension. With the AMeDAS and GIS data, climatic normals such, as monthly air temperature, were prepared for each grid-point covering Japan in the early 1990s. The mesh climatic data system gave the opportunity to estimate the daily mean temperature at each grid-point so that real-time weather information would be available at every mesh (1 km^2) all over Japan.

Figure 2. Automated Meteorological Data Acquisition System and its distribution in Tohoku Region



Source: Yajima, M., 1994.

Table 1. Availability of data in Japan

Meteorological Data: Mesh-data such as daily mean temperature and solar radiation at 1 * 1 km grid-point through the Automated Meteorological Data Acquisition System (AmeDAS)
Land-use and other Geographic Information: Mesh-data at 1 x 1 km grid-point from GIS
Crop Data: Varieties, dates of sowing, transplanting, heading, harvesting and yield - from the Dept. of Statistics and Information, Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan.

Source: Yajima, M., 1994.

Table 2. Initial condition for crop simulation

Prefecture	Geo-climatic subdivision	Variety	Transplanting date	Leaf Age
Aomori	Aomori	Akihikari	May 19	4
	Tsugaru		May 18	4
	Nanbu		May 18	4
	Shimokita		May 22	4
Iwate	Kitakamijoryu	Akitakomachi	May 19	4
	Kitakamikaryu		May 14	4
	Tonanbu		May 19	4
	Shimoheii		May 20	4
	Hokubu		May 23	4
Miyagi	Nanbu	Sasanishiki	May 7	4
	Chubu		May 7	4
	Hokubu		May 8	4
	Tobo		May 7	4
Akita	Kenhoku	Akitakomachi	May 19	2
	Kenchuo		May 15	2
	Kennan		May 23	2
Yamagata	Murayama	Sasanishiki	May 22	4
	Mogami		May 22	4
	Okitama		May 20	4
	Shonai		May15	2
Fukushima	Nakadorihokubu	Koshihikari	May 16	2
	Nakadorinanbu		May 15	2
	Hamadori		May 13	2
	Aizu		May 20	2

Source: Yajima, M., 1994.

The investigation was focused on the Tohoku District involving the monitoring of Aomori, Iwate, Miyagi, Akita, Yamagata and Fukushima Prefectures in 1993. Each prefecture was divided into three to five subdivisions based on geographic and climatic conditions. Using the two previously mentioned models, crop development and percentage of sterility were estimated for the Tohoku district in 1993. The real-time mesh data on daily air temperatures at 1 km x 1 km grid-points was estimated using Seino's method with daily AMeDAS data. On the other hand, crop data was provided by the Ministry of Agriculture, Forestry and Fisheries (MAFF).

Results from the simulation

The rice varieties studied were Akihikari in the Aomori Prefecture, Akitakomachi in Iwate and Akita Prefectures, Sasanishiki in Miyagi and Yamagata Prefectures, and Koshihikari in the Fukushima Prefecture. Transplanting across the six prefectures was performed within the period, May 7-23, 1993.

Actual air temperature and climatic normal temperature

Based on real-time mesh data on air temperatures recorded over the Tohoku District during the period August 1-10, 1993, prefectures on the Pacific Ocean side, generally showed a cooler air temperature (below 17^{o} C) than the Prefectures on the Japan Sea side (19- 21^{o} C and in some areas above 21^{o} C) (Figure 3). The cool temperature in the northern part and most parts of the Pacific Ocean side of the Tohoku district is caused by the "Yamase", a cold anti-cyclone stationary on the Sea of Okhotsk that blows cold winds on the Pacific Ocean side of the Tohoku district.

Figure 3. Mesh data on air temperature over Tohoku district, August 1-10, 1993

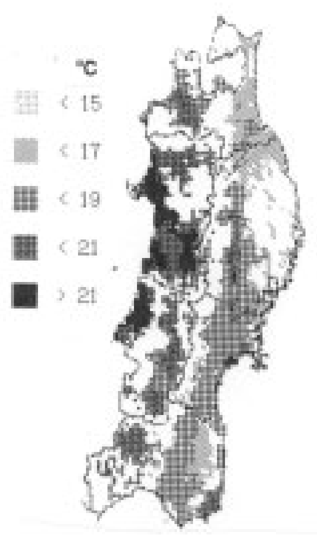
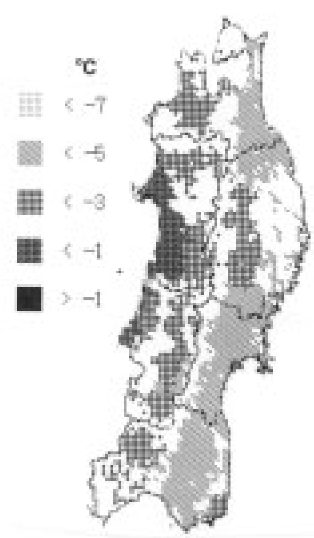


Figure 4. Deviation of air temperature from climatic normals in Tohoku district, August 1-10, 1993



Source: Yajima, M., 1994.

The spatial distribution of the difference in climatic normal temperature and actual temperature (mean normal temperature minus the actual temperature during the period of abnormally cool weather) for this period is shown in Figure 4. Prefectures on the Pacific Ocean side were in the range of below 3-5^{o} C compared with the climatic normal temperature covering about 20,000 km^{2}. Relatively lower temperature differences (1-3^{o} C) were observed in the Japan Sea side prefectures.

Heading dates

Using the real-time data on air temperatures, the heading dates of rice cultivars across the Tohoku District were estimated. The estimated heading dates of about 70 per cent of the Tohoku District corresponded to the period August 10-25. The heading dates of about 30 per cent of the rice production areas are likely to correspond to the period after August 26, and these areas are concentrated on the Pacific Ocean side particularly the northeastern parts (Figure 5). Correspondingly, delays in heading dates were in the range of 5-20 days in most parts of the Tohoku District, while beyond 20 days in the northeastern parts (Hokubu and Shimokita) which usually experience severe cold winds during the reproductive stage of the rice crop (Figure 6).

Figure 5. Estimated heading (days) of rice cultivars in Tohoku district. 1993.

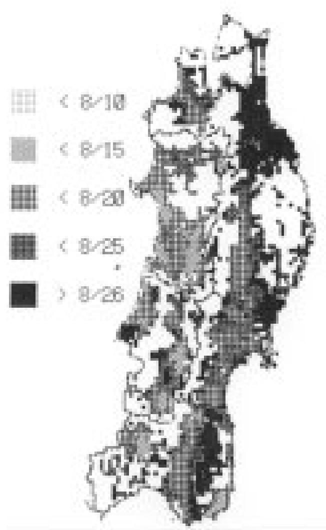
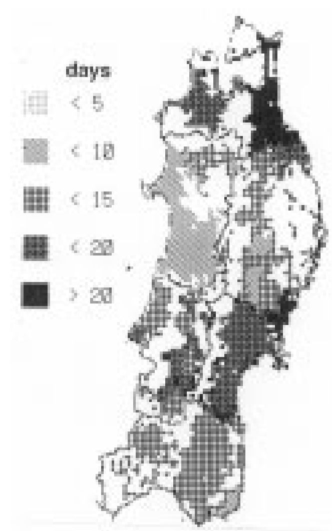


Figure 6. Estimated delay of heading of of rice cultivars in Tohoku district, 1993.

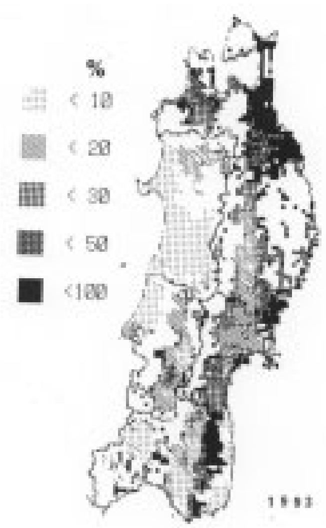


Source: Yajima, M., 1994.

Spikelet sterility and yield index

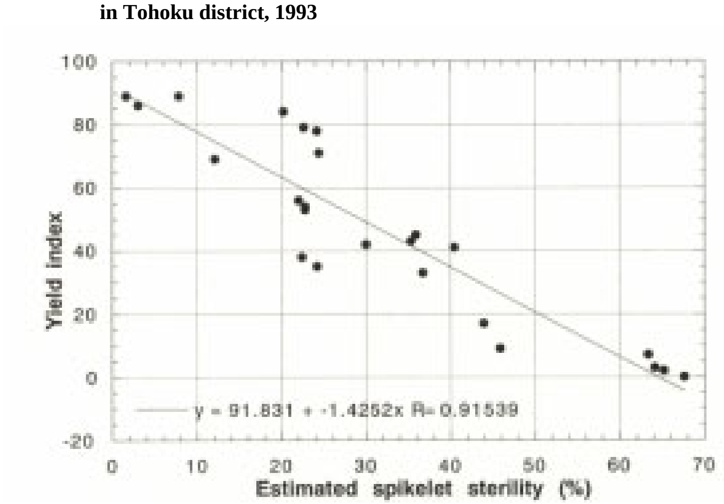
The percentage of sterility due to cool temperatures was estimated for the Tohoku district in 1993. Spikelet sterility estimates of 50-100 per cent were obtained in the Pacific Ocean side prefectures, particularly in areas with large negative temperature deviations (3-5^{o} C) from climatic normals. Spikelet sterility estimates for the prefectures on the Japan Sea side which ranged from 10-30 per cent (Figure 7) may be due to the negative deviation of air temperature from climatic normals by 1-3^{o} C, particularly during the meiosis of mother pollen cells until heading in these areas.

Figure 7. Spatial distribution of estimated spikelet sterility in Tohoku district, 1993



Source: Yajima, M., 1994.

Figure 8. Relationship between estimated spikelet sterility and actural yield index in Tohoku district, 1993



Source: Yajima, M., 1994.

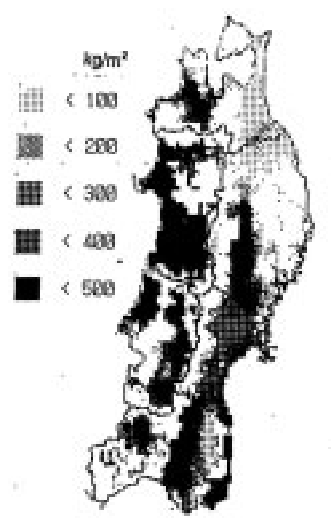
When the estimated spikelet sterility was plotted against the yield index (actual crop data), a highly significant negative linear relationship (R = -0.92***) was obtained (Figure 8), suggesting that the spikelet sterility model is suitable for prediction purposes. Based on the results, with the use of the real-time mesh data on temperatures, spikelet sterility could be monitored on a daily basis, aside from the development stage of the rice plant such as the heading date with the utilization of the automated weather data transfer for immediate results.

Rice growth and yield

As described in the methodology, the combined use of DVS, crop growth and spikelet sterility models leads to the estimation of the yield. In this case, daily mean temperature and solar radiation from the mesh data, and the crop growth data were used.

Two estimations of yields, using the rice crop model were carried out for the Tohoku District in 1993. First, by using the actual daily mean temperature and solar radiation, and second, by using the climatic normals for the daily mean temperature and solar radiation. Estimated yields based on the actual daily mean temperature and solar radiation were generally high (400-500 kg/10a) on the Japan Sea side, particularly in some parts of Aomori, and most parts of the Akita and Yamagata Prefectures. Low yield estimates were obtained (<100 kg/10a) on the Pacific Ocean side of the Aomori and Iwate Prefectures. However, the inland and southern portion of Iwate, and about 40 per cent of Fukushima ranged, between 200-400 kg/10a (Figure 9).

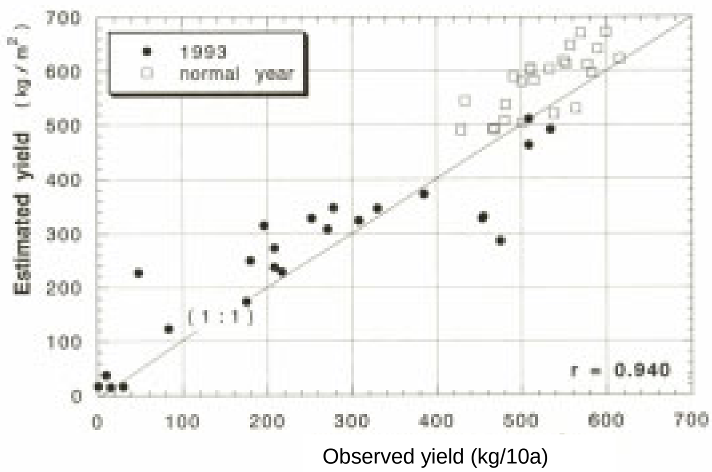
Figure 9. Estimated yields in Tohoku District based on actual daily mean temperature and solar radiation, 1993



Source: Yajima, M., 1994.

With the climatic normal as the basis of yield estimates, it is apparent that the estimated yield in the Japan Sea side prefectures (excluding Fukushima) were more than 550 kg/10a. These areas were consistently high yielding, even when yield estimates were based on actual temperature and solar radiation. Estimated potential yields in Aomori (Pacific Occean side) could be as high as 450 kg/10a under a normal climate, but yield estimates were below 100 kg/10a under the adversely cool temperatures. Similarly, the estimated potential yields in the Iwate and Miyagi Prefectures decreased by 100-350 kg/10a under the adverse cool weather. Fukushima was the least affected by the adverse cool weather.

Figure 10. The actual and estimated yields in Tohoku District as plotted in the 1:1 line (slope=1), 1993



Source: Yajima, M., 1994.

As a check for the reliability of the estimated yield, actual yields under climatic normals and cool weather conditions were plotted against estimated yields under two climatic conditions (Figure 10). The good fit of the actual and estimated yields in the unity slope proved the reliability of the rice crop model in the monitoring and prediction of yields.

"Climatic Early Warning System against cool summer damage" by the National Agricultural Research Center for Tohoku Region

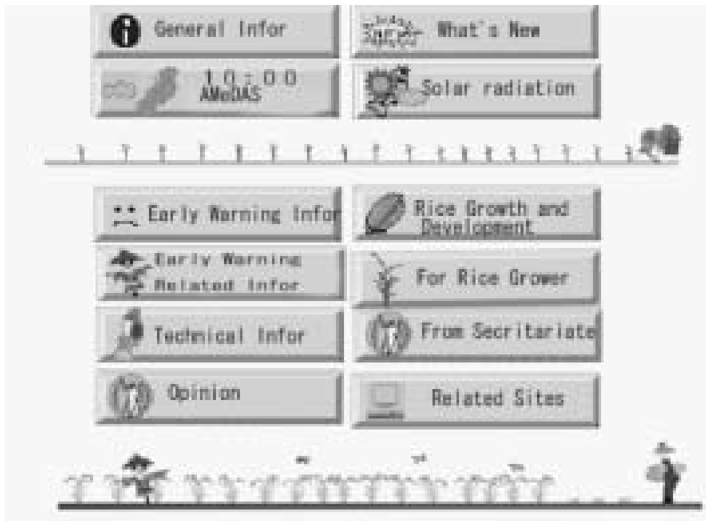
Cool summer damage in 1993 became the great damage called the 'once hundred years'. It affected the local community greatly. Then, Tohoku National Agricultural Experiment Station decided to set up an Early Monitoring Research Team in cooperation with the Tohoku Regional Agricultural Administration Office, prefectural agriculture experiment stations and Sendai district meteorological observatory in April, 1995.

Here, the activity of the early monitoring research team is simply introduced.

The research team has two unique points. The first is that members of the team are composed of researchers from different fields. The other is the participation of rice growers, so called "monitor farmers", for exchanging information, ideas and data to reduce or minimize cool summer damage of rice. With the participation of the monitor-rice growers, who are more than 30 farmers in Tohoku district, information on rice growth, like plant height and leaf age, will be sent to the research team at certain intervals. In addition, the exchange of views are also carried out once a week on water temperature, conditions on disease or insect damage and weed control in their paddy fields between the research team and monitor farmers.

This data and observed or estimated information by the team is open to the public, through the internet, free of charge (Figure 11).

Figure 11. Menu page of "Early Monitoring System"
http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi
Currently Japanese version only



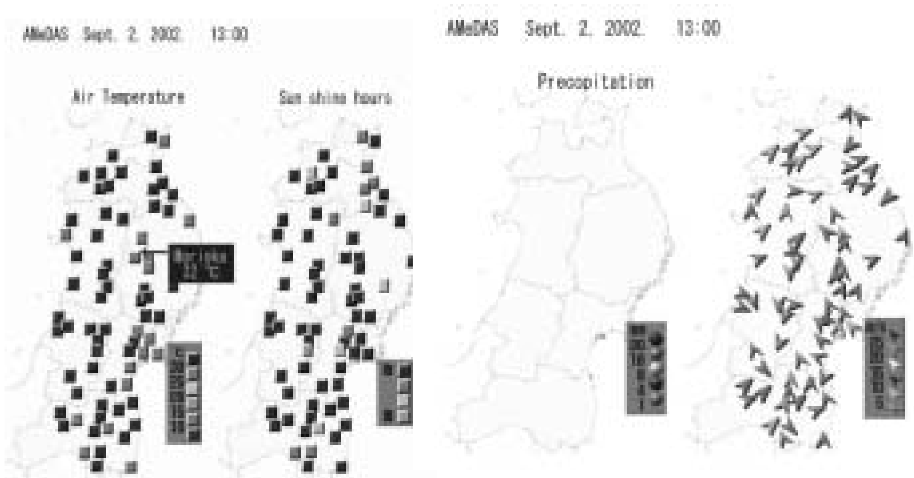
Menu Page of "Early Monitoring System" on the website

Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

AMeDAS Page

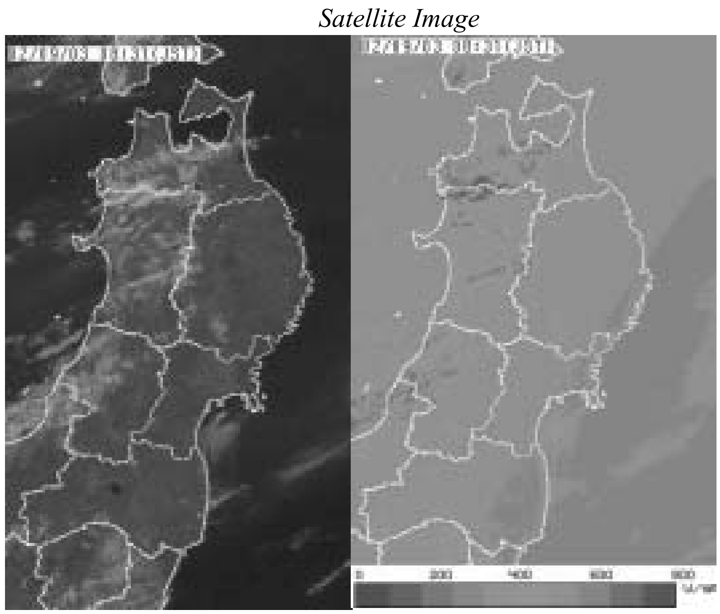
Real time weather data like air temperature, sunshine hours, precipitation and wind speed/direction are available (Figure 12 and 13).

Figure 12. Real time AMeDAS data on the home page



Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

Figure 13. Satellite Image and estimated solar radiation courtesy of Kawamura Laboratory, Tohoku University

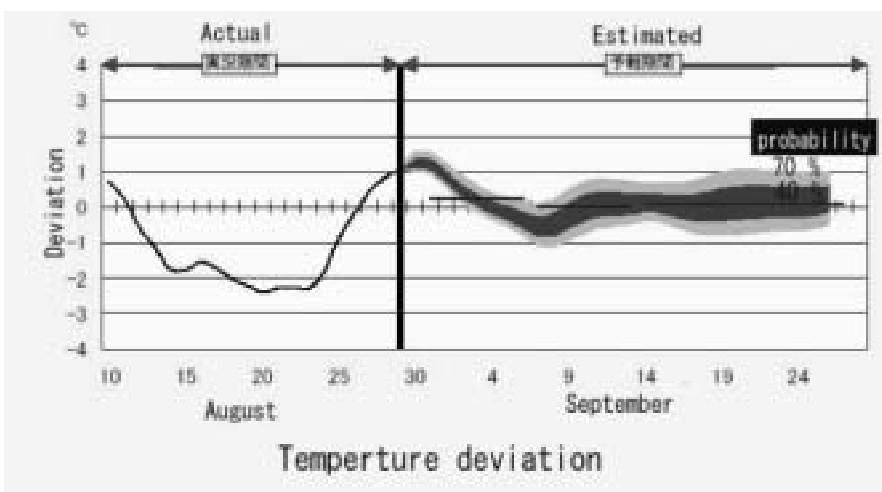


Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

Early Warning Information

The weather information which the research staff notices at present is informed. For example Early Warning Information No.19 (Aug 31, 2002) is shown below (Figure 14).

Figure 14. A sample of early warning information



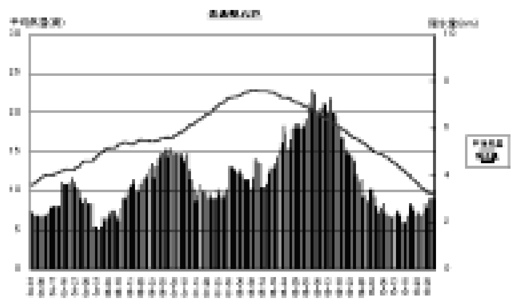
Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

- Sendai Meteorological Observatory announced the one-month weather forecast on August 30.
- The temperature will be the common year level.

Instruction of rice cultivation for rice growers

Instruction on safety rice cultivation against cool summer damage is also provided for rice growers covering 90 points in Tohoku district.

Figure 15. A sample of an instruction of rice cultivation to inform safe rice growing



Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

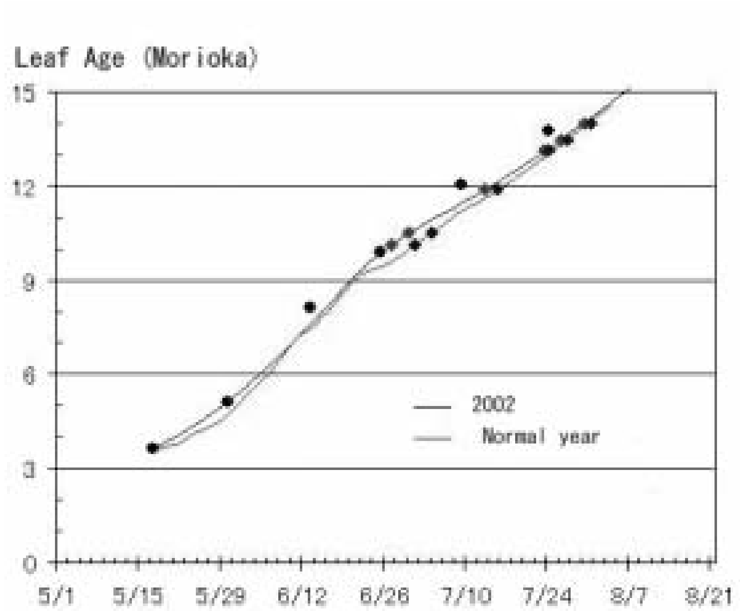
- Instruction of safety cropping for rice growers is based on Uchijima's model.
  Y = S { 4. 1 4 – 0 . 1 3 (2 1 . 4 – T) ^ 2 }
- Instruction of suitable transplanting, heading and harvest times for each point in the Tohoku Region.

Real time estimation for rice leaf blast

Figure 16. Predicted area where rice growers should keep watch against rice leaf blast. Area is estimated by Koshimizu's model using AMeDAS data

Estimated crop growth at fixed points

Figure 17. Estimated crop growth in the fields of monitor farmers



	Leaf number index (Aug. 4)	Panicle neck node differentiation	Panicle initiation	Meiosis
Normal year	14.7	Jun. 27	Jul. 13	Jul. 26
This year	14.6	Jul. 1	Jul. 15	Jul. 27

To obtain more information for the users we link to the Technical Information Page provided by the Tohoku Agriculture Administration Office and Pest Management Page in each prefecture (Figure 16 and 17).

The Department of Statistics and Information, Ministry of Agriculture, Forestry and Fisheries announced this year that 53.1 per cent of the farmers in Japan possessed a personal computer and 32.8 per cent of the farmers have used the internet.

The actual number of hits to the home page was more than two million seven hundred thousand in 2001. As this number of hits shows, I believe that the "Early monitoring system" of our research center is one of the useful tools for the farmers in the Tohoku district.

Summary and conclusions

Two components of a rice crop model, namely Development Stage Model and Spikelet Sterility Model were used to develop a monitoring and forecasting system of rice development and spikelet sterility in the Tohoku district, Japan in 1993. Actual crop data was provided by MAFF. Meteorological data (real-time weather data) and geographic information of the monitored area were provided through AMeDAS and GIS, respectively. With the use of mesh-weather data, rice models were developed and varietal characteristics of rice planted in the monitored area, spatial distribution of mean air temperatures and their deviation from climatic normals, as well as the spikelet sterility due to cool temperature were determined. A significant negative linear correlation was obtained between the estimated spikelet sterility and yield. The results suggest the importance of the use of a crop model for the monitoring and forecasting of rice development stages and spikelet sterility at the regional level or in areas affected by cool temperature damage. With this method, extension staff could easily provide information on the possible occurrence of spikelet sterility in particular areas, which may enable the farmers to take the necessary counter-measures to minimize the yield reduction due to the cool temperatures. This method could also be applied under tropical conditions in the cool elevated areas.

In the meantime, the information service to the farmhouse is also important. The example, early caution system developed by the National Agriculture Research Center for Tohoku Region, Japan was introduced. It is concluded that the "Early monitoring system" is a useful tool for rice growers not only to receive information on rice growth or weather, but also to communicate or exchange views with researchers on rice cultivation techniques to reduce or minimize rice yield reduction.

References

Horie, T, 1987. A model for evaluating climatic productivity and water balance of irrigated rice and its application to Southwest Asia. Southwest Asian Studies, Kyoto Univ. 25:62-71.

Horie, T. and Nakagawa, H., 1990. Modeling and prediction of development process in rice: 1. Structure and method of parameter estimation of a model for simulating developmental process toward heading. Japan Journal Crop Science 59:687-695.

Horie, T., Yajima, M. and Nakagawa, H., 1992. Yield forecasting. Agricultural systems 40: 211-236.

Seino, S., 1993. An estimation of distribution of meteorological elements using GIS and AMeDAS data. Jap. Journal Agr. Met. 48: 379-383.

Yajima, M., Nitto, A. and Seino, H., 1989. Estimation of percent sterility of rice spikelets with DVS model. Abstract for 1989. Ann. Meeting Agr. Met. Soc., Japan.

Yajima, M., 1994. Agro-meteorological estimation of rice growth and yield. *In* Great Weather Disaster in Heisei ed. Agr. Met. Soc., Japan. Norin Tokei Kyokai.

Yajima, M., 1996a. Monitoring regional rice development and cool-summer damage. JARQ 30:139-143.

Yajima, M., 1996b. Monitoring and forcasting of rice growth and development using crop-weather model. Proc. 2nd Asia Crop Sci. Conf., Crop Sci. Soc. Japan.

Early Warning System against Cool Summer Damage: Case of Northern Japan

Masaharu Yajima[*]

Introduction

Rice yield has been increased tremendously by the development of improved nursery techniques, new varieties resistant to lodging and diseases, and new yield-enhancing agrochemicals. Although high rice yields are commonly attained by the rice farmers, yield fluctuations sometimes occur due to unfavorable weather conditions during the rice cropping season in particular areas. For instance, severe spikelet sterility due to cool weather that occurred during the meiosis to flowering stage of the rice crop in some areas of Tohoku District in 1980, 1989 and 1993, greatly reduced yield. The severity of spikelet sterility, due to cool weather, is an alarming situation that needs attention through redirection of research focus to varietial improvement, improvement of cultivation techniques and/or evasion of the damage.

As an initial response to the problem, a quantitative technique to monitor crop growth and development was developed based on real time climatic data. In such cases, crop and weather information could be provided to the farmers for the possible reduction or avoidance of spikelet sterility due to cool weather knowing the agronomic characteristics of the cultivar they will plant.

This paper intends to describe the research approach and present initial results of wide area monitoring of crop growth and development using a rice crop model and introduce the current version of “Climatic Early Warning System against cool summer damage” by the National Agricultural Research Center for the Tohoku Region.

Monitoring crop growth and development using a rice crop model

Crop models

The approach involved the use of the development stage, spikelet sterility yield models and crop and geo-climatic data sets for the development of the prediction system.

Development stage model for rice

Based on the development stage (DVS) model designed by Prof. T. Horie (1987), values of 0, 1, and 2 are assigned to emergence (seed germination), heading and physiological maturity, respectively. The value of DVS at any point of crop development is calculated by integrating the developmental rate (DVR) with time:

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$$DVS\ (t) = \Sigma\ DVR\ i\ , \qquad (1)$$

where: DVS(t) is the developmental stage on the ith day, and DVR i is the development rate on the ith day from emergence. Horie and Nakagawa (1990), suggested that DVR, from emergence to heading of rice plant, could be expressed as a function of daylength (L) and daily mean temperature (T) such as:

$$DVR = 1/G * [1 - exp\ \{B(L - Lc)\}] \ / \ [1 - exp\{ -A\ (T - Th)\}], \qquad (2)$$

or

$$DVR = a\ (T - To), \qquad (3)$$

Where, Lc, T h, To, A and B are parameters (coefficients).

Equation 3 is used when transplanting dates are fixed and when rice varieties planted are non or weakly photosensitive. This equation is only applicable when DVR increases linearly with the temperature.

Dry matter accumulation

Generally, dry matter accumulation at any point of rice growth is proportional to accumulated solar radiation intercepted by the canopy, except at the final stage of rice growth when DVS is close to 2. The model used to estimate daily dry matter increase was adopted from Monteith (1977):

$$dW \ / \ dt = K_1(N) * S_0\ exp\ \{ 1 - (K_2 * F)\} \qquad (4)$$

where: dW/dt is the daily change in dry weight (g/m^2/day); K_1(N) is the radiation-use efficiency (g/ m^2/MJ); and F is the leaf area index (LAI). To generate LAI in eq.(4), the following model was modified as a function of basal fertilizer application, which is based on SIMRIW by Horie (1987).

$$dF/dt = R_m(N)\ [\ 1- exp\{ - K_f(N)(T-T_0)\}]*[\{1- (F/F_a(N))^n\}F] \qquad (5)$$
$$dF/dt = 0 \text{ for } T< T_0 \text{ and } dF/dt = -.01 * LAI_{max} * DVS$$

where: dF/dt is the daily change in LAI. R_m(N), K_f(N), F_a(N) are parameters depending on the amount of nitrogen (N) application. LAI_{max} is LAI at heading.

After heading, it was assumed that K_1(N) is reduced to .7 of its value used before heading.

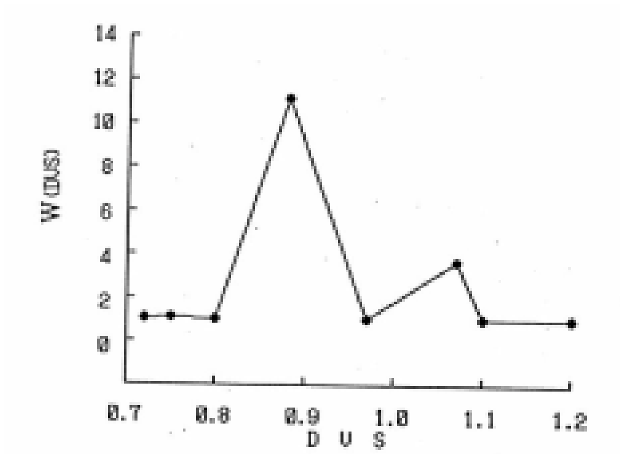
Spikelet sterility model for rice

The spikelet sterility model on the relationship between spikelet sterility and cool temperature sensitivity of rice plants at the panicle development stage was proposed by Yajima *et al*. (1989), with the following equation:

$$G = \bullet\ (To - Ti)\ W(DVS)$$
$$\text{for } Ti < 18.9 \text{ and, } 1.20 > DVS > 0.72 \qquad (6)$$

Where, W(DVS) is the panicle sensitivity factor to cool temperature as a function of DVS. The value of W was based on the spikelet sterility data obtained by using the var. Sasanishiki in Miyagi Prefecture (1988). Rice shows two sensitivity peaks to cool temperatures. The first is observed at DVS = 0.88 which corresponds to the meiosis of the pollen mother cell, and the second is at DVS = 1.07 which corresponds to the mid-flowering stage (Figure 1).

Figure 1. Effect of cool temperature on sensitivity to spikelet sterility



Source: Yajima, *et al.*, 1994.

Yield

Grain yield is proportional to dry matter accumulation at physiological maturity (W_m) and expressed as follows:

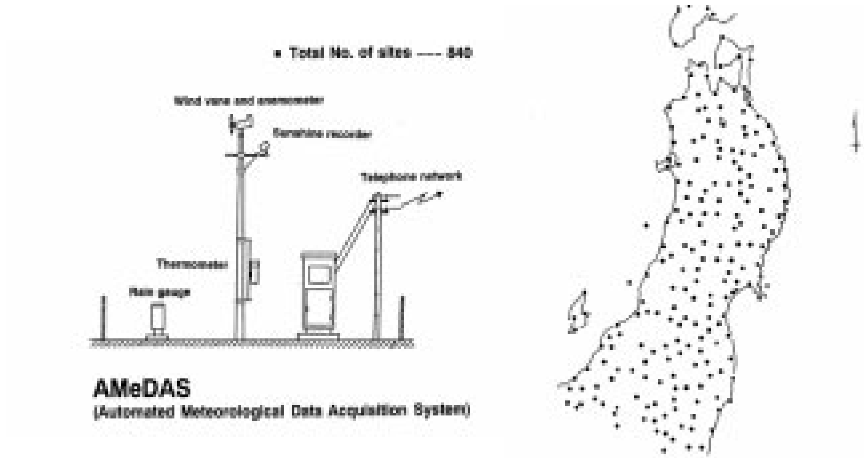
$$Y = HI * (1 - UF/100) * W_m \qquad (7)$$

Where, Y is the grain yield (brown rice) and HI is harvest index with a value of 0.4.

Crop and weather data

Crop data such as, variety planted, transplanting date, heading date and actual paddy yield were provided by the Dept. of Statistics, Ministry of Agriculture, Forestry and Fisheries (MAFF). Meteorological data such as air temperature, has been collected from 860 sites all over Japan since 1974. The Automated Meteorological Data Acquisition System (AMeDAS), provided the real-time weather information throughout Japan. The Geographic Information System (GIS) in Japan also provided the information on land elevation, land use, and other geographical data for each rectangular grid-point, 1 km x 1 km in dimension. With the AMeDAS and GIS data, climatic normals such, as monthly air temperature, were prepared for each grid-point covering Japan in the early 1990s. The mesh climatic data system gave the opportunity to estimate the daily mean temperature at each grid-point so that real-time weather information would be available at every mesh (1 km^2) all over Japan.

Figure 2. Automated Meteorological Data Acquisition System and its distribution in Tohoku Region



Source: Yajima, M., 1994.

Table 1. Availability of data in Japan

Meteorological Data:
Mesh-data such as daily mean temperature and solar radiation at 1 * 1 km grid-point through the Automated Meteorological Data Acquisition System (AmeDAS)

Land-use and other Geographic Information:
Mesh-data at 1 x 1 km grid-point from GIS

Crop Data:
Varieties, dates of sowing, transplanting, heading, harvesting and yield - from the Dept. of Statistics and Information, Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan.

Source: Yajima, M., 1994.

Table 2. Initial condition for crop simulation

Prefecture	Geo-climatic subdivision	Variety	Transplanting date	Leaf Age
Aomori	Aomori	Akihikari	May 19	4
	Tsugaru		May 18	4
	Nanbu		May 18	4
	Shimokita		May 22	4
Iwate	Kitakamijoryu	Akitakomachi	May 19	4
	Kitakamikaryu		May 14	4
	Tonanbu		May 19	4
	Shimoheii		May 20	4
	Hokubu		May 23	4
Miyagi	Nanbu	Sasanishiki	May 7	4
	Chubu		May 7	4
	Hokubu		May 8	4
	Tobo		May 7	4
Akita	Kenhoku	Akitakomachi	May 19	2
	Kenchuo		May 15	2
	Kennan		May 23	2
Yamagata	Murayama	Sasanishiki	May 22	4
	Mogami		May 22	4
	Okitama		May 20	4
	Shonai		May15	2
Fukushima	Nakadorihokubu	Koshihikari	May 16	2
	Nakadorinanbu		May 15	2
	Hamadori		May 13	2
	Aizu		May 20	2

Source: Yajima, M., 1994.

The investigation was focused on the Tohoku District involving the monitoring of Aomori, Iwate, Miyagi, Akita, Yamagata and Fukushima Prefectures in 1993. Each prefecture was divided into three to five subdivisions based on geographic and climatic conditions. Using the two previously mentioned models, crop development and percentage of sterility were estimated for the Tohoku district in 1993. The real-time mesh data on daily air temperatures at 1 km x 1 km grid-points was estimated using Seino's method with daily AMeDAS data. On the other hand, crop data was provided by the Ministry of Agriculture, Forestry and Fisheries (MAFF).

Results from the simulation

The rice varieties studied were Akihikari in the Aomori Prefecture, Akitakomachi in Iwate and Akita Prefectures, Sasanishiki in Miyagi and Yamagata Prefectures, and Koshihikari in the Fukushima Prefecture. Transplanting across the six prefectures was performed within the period, May 7-23, 1993.

Actual air temperature and climatic normal temperature

Based on real-time mesh data on air temperatures recorded over the Tohoku District during the period August 1-10, 1993, prefectures on the Pacific Ocean side, generally showed a cooler air temperature (below 17^{o} C) than the Prefectures on the Japan Sea side (19- 21^{o} C and in some areas above 21^{o} C) (Figure 3). The cool temperature in the northern part and most parts of the Pacific Ocean side of the Tohoku district is caused by the "Yamase", a cold anti-cyclone stationary on the Sea of Okhotsk that blows cold winds on the Pacific Ocean side of the Tohoku district.

Figure 3. Mesh data on air temperature over Tohoku district, August 1-10, 1993

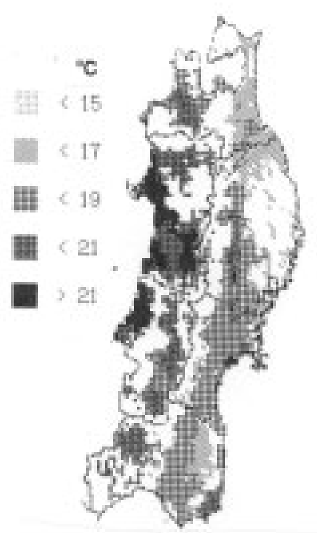
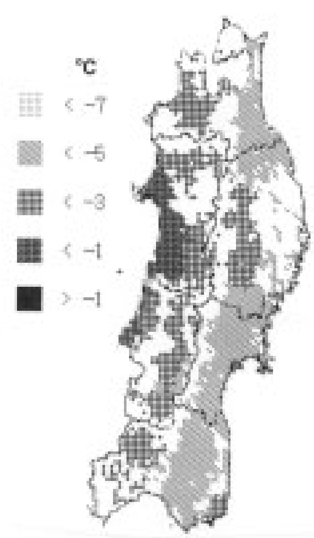


Figure 4. Deviation of air temperature from climatic normals in Tohoku district, August 1-10, 1993



Source: Yajima, M., 1994.

The spatial distribution of the difference in climatic normal temperature and actual temperature (mean normal temperature minus the actual temperature during the period of abnormally cool weather) for this period is shown in Figure 4. Prefectures on the Pacific Ocean side were in the range of below 3-5^{o} C compared with the climatic normal temperature covering about 20,000 km^2. Relatively lower temperature differences (1-3^{o} C) were observed in the Japan Sea side prefectures.

Heading dates

Using the real-time data on air temperatures, the heading dates of rice cultivars across the Tohoku District were estimated. The estimated heading dates of about 70 per cent of the Tohoku District corresponded to the period August 10-25. The heading dates of about 30 per cent of the rice production areas are likely to correspond to the period after August 26, and these areas are concentrated on the Pacific Ocean side particularly the northeastern parts (Figure 5). Correspondingly, delays in heading dates were in the range of 5-20 days in most parts of the Tohoku District, while beyond 20 days in the northeastern parts (Hokubu and Shimokita) which usually experience severe cold winds during the reproductive stage of the rice crop (Figure 6).

Figure 5. Estimated heading (days) of rice cultivars in Tohoku district. 1993.

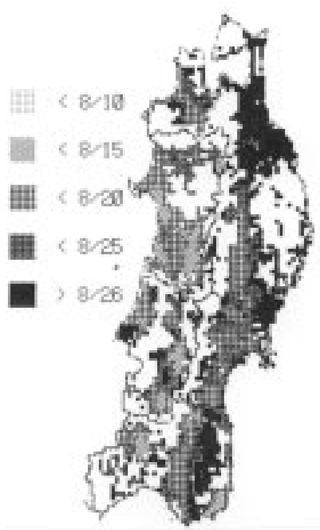
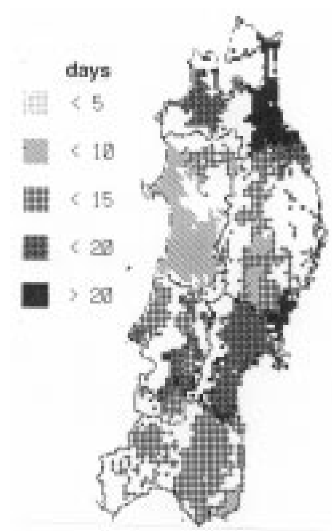


Figure 6. Estimated delay of heading of of rice cultivars in Tohoku district, 1993.

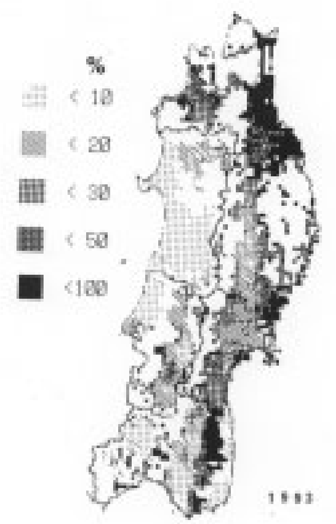


Source: Yajima, M., 1994.

Spikelet sterility and yield index

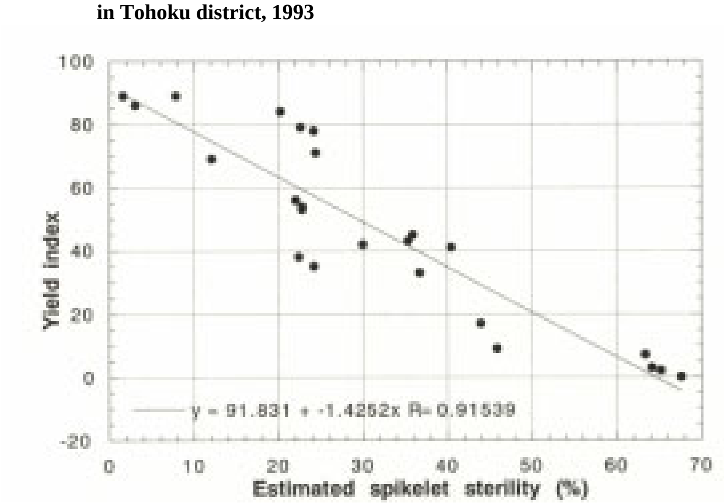
The percentage of sterility due to cool temperatures was estimated for the Tohoku district in 1993. Spikelet sterility estimates of 50-100 per cent were obtained in the Pacific Ocean side prefectures, particularly in areas with large negative temperature deviations (3-5^{o} C) from climatic normals. Spikelet sterility estimates for the prefectures on the Japan Sea side which ranged from 10-30 per cent (Figure 7) may be due to the negative deviation of air temperature from climatic normals by 1-3^{o} C, particularly during the meiosis of mother pollen cells until heading in these areas.

Figure 7. Spatial distribution of estimated spikelet sterility in Tohoku district, 1993



Source: Yajima, M., 1994.

Figure 8. Relationship between estimated spikelet sterility and actural yield index in Tohoku district, 1993



Source: Yajima, M., 1994.

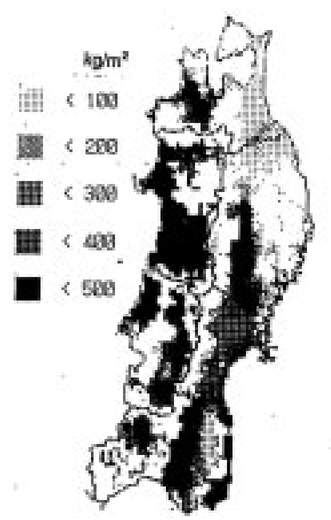
When the estimated spikelet sterility was plotted against the yield index (actual crop data), a highly significant negative linear relationship (R = -0.92***) was obtained (Figure 8), suggesting that the spikelet sterility model is suitable for prediction purposes. Based on the results, with the use of the real-time mesh data on temperatures, spikelet sterility could be monitored on a daily basis, aside from the development stage of the rice plant such as the heading date with the utilization of the automated weather data transfer for immediate results.

Rice growth and yield

As described in the methodology, the combined use of DVS, crop growth and spikelet sterility models leads to the estimation of the yield. In this case, daily mean temperature and solar radiation from the mesh data, and the crop growth data were used.

Two estimations of yields, using the rice crop model were carried out for the Tohoku District in 1993. First, by using the actual daily mean temperature and solar radiation, and second, by using the climatic normals for the daily mean temperature and solar radiation. Estimated yields based on the actual daily mean temperature and solar radiation were generally high (400-500 kg/10a) on the Japan Sea side, particularly in some parts of Aomori, and most parts of the Akita and Yamagata Prefectures. Low yield estimates were obtained (<100 kg/10a) on the Pacific Ocean side of the Aomori and Iwate Prefectures. However, the inland and southern portion of Iwate, and about 40 per cent of Fukushima ranged, between 200-400 kg/10a (Figure 9).

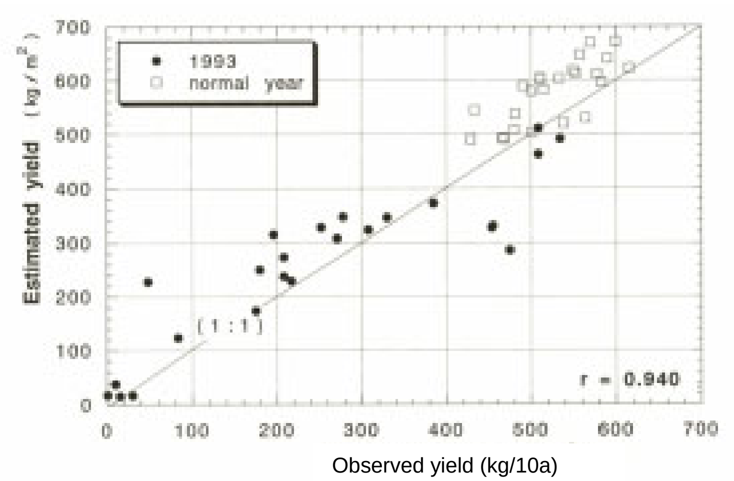
Figure 9. Estimated yields in Tohoku District based on actual daily mean temperature and solar radiation, 1993



Source: Yajima, M., 1994.

With the climatic normal as the basis of yield estimates, it is apparent that the estimated yield in the Japan Sea side prefectures (excluding Fukushima) were more than 550 kg/10a. These areas were consistently high yielding, even when yield estimates were based on actual temperature and solar radiation. Estimated potential yields in Aomori (Pacific Occean side) could be as high as 450 kg/10a under a normal climate, but yield estimates were below 100 kg/10a under the adversely cool temperatures. Similarly, the estimated potential yields in the Iwate and Miyagi Prefectures decreased by 100-350 kg/10a under the adverse cool weather. Fukushima was the least affected by the adverse cool weather.

Figure 10. The actual and estimated yields in Tohoku District as plotted in the 1:1 line (slope=1), 1993



Source: Yajima, M., 1994.

As a check for the reliability of the estimated yield, actual yields under climatic normals and cool weather conditions were plotted against estimated yields under two climatic conditions (Figure 10). The good fit of the actual and estimated yields in the unity slope proved the reliability of the rice crop model in the monitoring and prediction of yields.

"Climatic Early Warning System against cool summer damage" by the National Agricultural Research Center for Tohoku Region

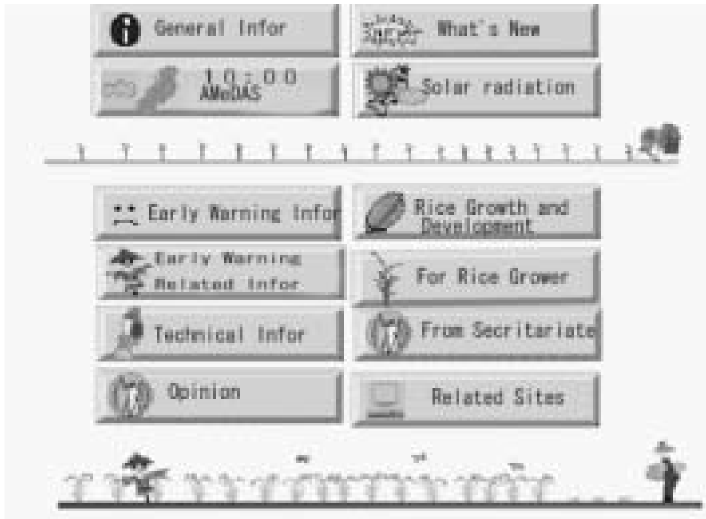
Cool summer damage in 1993 became the great damage called the 'once hundred years'. It affected the local community greatly. Then, Tohoku National Agricultural Experiment Station decided to set up an Early Monitoring Research Team in cooperation with the Tohoku Regional Agricultural Administration Office, prefectural agriculture experiment stations and Sendai district meteorological observatory in April, 1995.

Here, the activity of the early monitoring research team is simply introduced.

The research team has two unique points. The first is that members of the team are composed of researchers from different fields. The other is the participation of rice growers, so called "monitor farmers", for exchanging information, ideas and data to reduce or minimize cool summer damage of rice. With the participation of the monitor-rice growers, who are more than 30 farmers in Tohoku district, information on rice growth, like plant height and leaf age, will be sent to the research team at certain intervals. In addition, the exchange of views are also carried out once a week on water temperature, conditions on disease or insect damage and weed control in their paddy fields between the research team and monitor farmers.

This data and observed or estimated information by the team is open to the public, through the internet, free of charge (Figure 11).

Figure 11. Menu page of "Early Monitoring System"
http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi
Currently Japanese version only



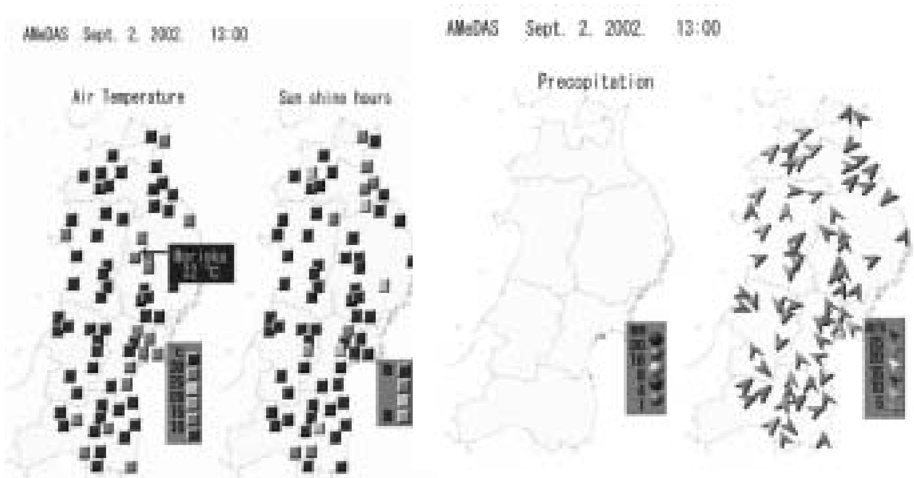
Menu Page of "Early Monitoring System" on the website

Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

AMeDAS Page

Real time weather data like air temperature, sunshine hours, precipitation and wind speed/direction are available (Figure 12 and 13).

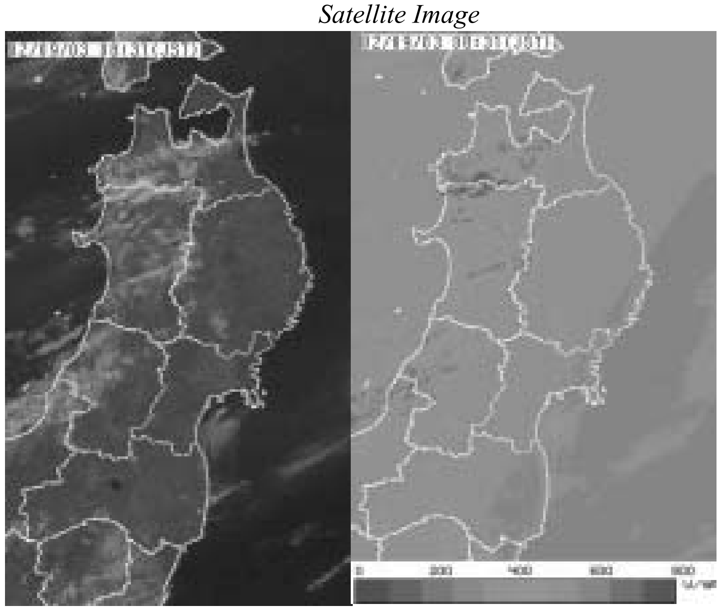
Figure 12. Real time AMeDAS data on the home page



Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

Figure 13. Satellite Image and estimated solar radiation courtesy of Kawamura Laboratory, Tohoku University

Satellite Image

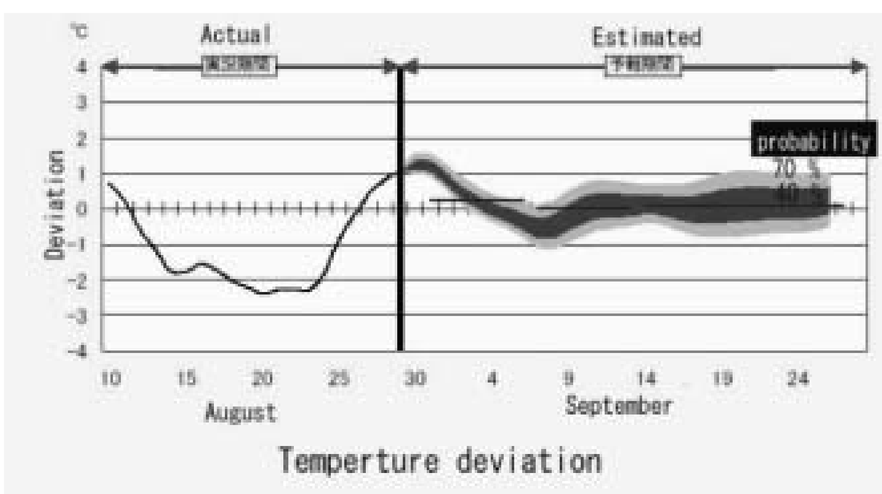


Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

Early Warning Information

The weather information which the research staff notices at present is informed. For example Early Warning Information No.19 (Aug 31, 2002) is shown below (Figure 14).

Figure 14. A sample of early warning information



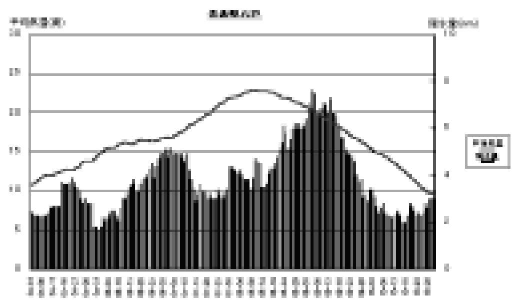
Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

- Sendai Meteorological Observatory announced the one-month weather forecast on August 30.
- The temperature will be the common year level.

Instruction of rice cultivation for rice growers

Instruction on safety rice cultivation against cool summer damage is also provided for rice growers covering 90 points in Tohoku district.

Figure 15. A sample of an instruction of rice cultivation to inform safe rice growing



Source: http://tohoku.naro.affrc.go.jp/cgi-bin/reigai.cgi

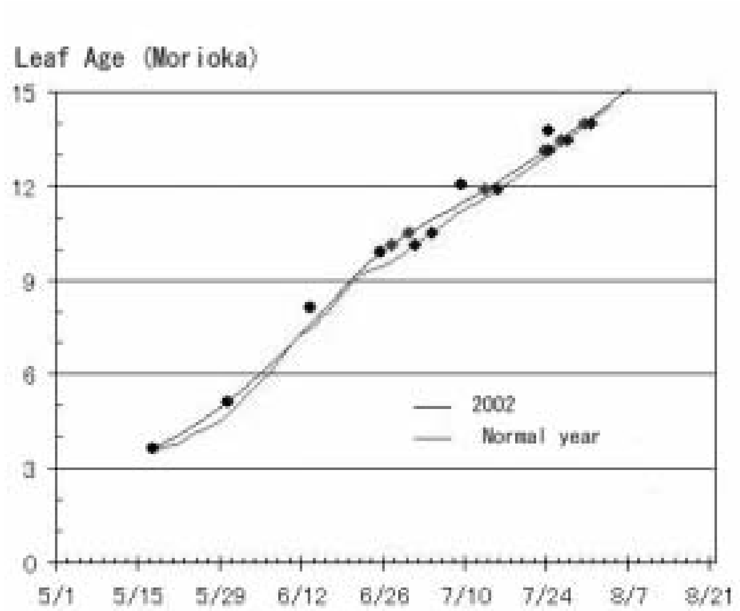
- Instruction of safety cropping for rice growers is based on Uchijima's model.
  Y = S { 4. 1 4 – 0 . 1 3 (2 1 . 4 – T) ^ 2 }
- Instruction of suitable transplanting, heading and harvest times for each point in the Tohoku Region.

Real time estimation for rice leaf blast

Figure 16. Predicted area where rice growers should keep watch against rice leaf blast. Area is estimated by Koshimizu's model using AMeDAS data

Estimated crop growth at fixed points

Figure 17. Estimated crop growth in the fields of monitor farmers



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Summary and conclusions

Two components of a rice crop model, namely Development Stage Model and Spikelet Sterility Model were used to develop a monitoring and forecasting system of rice development and spikelet sterility in the Tohoku district, Japan in 1993. Actual crop data was provided by MAFF. Meteorological data (real-time weather data) and geographic information of the monitored area were provided through AMeDAS and GIS, respectively. With the use of mesh-weather data, rice models were developed and varietal characteristics of rice planted in the monitored area, spatial distribution of mean air temperatures and their deviation from climatic normals, as well as the spikelet sterility due to cool temperature were determined. A significant negative linear correlation was obtained between the estimated spikelet sterility and yield. The results suggest the importance of the use of a crop model for the monitoring and forecasting of rice development stages and spikelet sterility at the regional level or in areas affected by cool temperature damage. With this method, extension staff could easily provide information on the possible occurrence of spikelet sterility in particular areas, which may enable the farmers to take the necessary counter-measures to minimize the yield reduction due to the cool temperatures. This method could also be applied under tropical conditions in the cool elevated areas.

In the meantime, the information service to the farmhouse is also important. The example, early caution system developed by the National Agriculture Research Center for Tohoku Region, Japan was introduced. It is concluded that the “Early monitoring system” is a useful tool for rice growers not only to receive information on rice growth or weather, but also to communicate or exchange views with researchers on rice cultivation techniques to reduce or minimize rice yield reduction.

References

Horie, T, 1987. A model for evaluating climatic productivity and water balance of irrigated rice and its application to Southwest Asia. Southwest Asian Studies, Kyoto Univ. 25:62-71.

Horie, T. and Nakagawa, H., 1990. Modeling and prediction of development process in rice: 1. Structure and method of parameter estimation of a model for simulating developmental process toward heading. Japan Journal Crop Science 59:687-695.

Horie, T., Yajima, M. and Nakagawa, H., 1992. Yield forecasting. Agricultural systems 40: 211-236.

Seino, S., 1993. An estimation of distribution of meteorological elements using GIS and AMeDAS data. Jap. Journal Agr. Met. 48: 379-383.

Yajima, M., Nitto, A. and Seino, H., 1989. Estimation of percent sterility of rice spikelets with DVS model. Abstract for 1989. Ann. Meeting Agr. Met. Soc., Japan.

Yajima, M., 1994. Agro-meteorological estimation of rice growth and yield. *In* Great Weather Disaster in Heisei ed. Agr. Met. Soc., Japan. Norin Tokei Kyokai.

Yajima, M., 1996a. Monitoring regional rice development and cool-summer damage. JARQ 30:139-143.

Yajima, M., 1996b. Monitoring and forcasting of rice growth and development using crop-weather model. Proc. 2nd Asia Crop Sci. Conf., Crop Sci. Soc. Japan.

Outline of the Research Project, “Stabilization of Upland Agriculture and Rural Development in El Nino Vulnerable Countries (ELNINO)”

Shigeki Yokoyama[*]

Position of the project

The ESCAP CGPRT Centre has been implementing a three-year research project, “Stabilization of Upland Agriculture and Rural Development in El Nino Vulnerable Countries (ELNINO),” from April 2000 to March 2003, funded by the Japanese government. This research activity is in line with Theme 3 of the Research and Development Programme of the CGPRT Centre. Under this theme, namely, “Sustainable Agriculture and Resource Management,” the Centre aims to operationalize the concept of sustainable agriculture and resource management and identify economic opportunities and direction of market formation in resource use. The theme brings together biophysical and socio-economic issues, and focuses on natural resources such as land and water, as well as human resources. Environmental issues, climatic variation and change can also be addressed in this theme (The CGPRT Centre, 1998, p.10).

El Nino related large-scale abnormal weather is one of the most important common problems faced by agricultural sectors of the ESCAP member countries. The impact of this natural disaster is so great that it may cause a sharp decline in agricultural production in general, and food production in particular. The recent tendency of increasing irregularity and frequency of the El Nino occurrence is the most risky factor to national food security and the livelihoods of rural people in the region. This is a regional problem that should be dealt with by regional cooperation. The CGPRT Centre’s initiative to organize this collaborative research is in line with the Centre’s function as the regional coordination centre for research and development according to Commission Resolution 220 (XXXVIII) of ESCAP 38th Session in 1982 (ESCAP, 1982). Development of disaster prevention measures, the ultimate target of this study, basically aims at solving national food security problems as well as protecting the rural economy of the ESCAP member countries, which is one of the CGPRT Centre’s objectives according to the Commission Resolution. This study is conducted mainly in the upland areas of the participating countries, which is the agroecoregional focus of the Centre.

Collaborative institutes

Five countries, Indonesia, Malaysia, Papua New Guinea, the Philippines, and Thailand, are participating in the project. Located in the west of the equatorial Pacific Ocean, the countries commonly suffer from climatic abnormalities, drought in particular, in El Nino years. The project is being undertaken in close collaboration with the following six institutes from the participating countries. The Center for Agro-Socio Economic Research and Development

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(CASERD), the Department of Agriculture, Indonesia; the Economic and Technology Management Research Center of Malaysian Agricultural Research and Development Institutes (MARDI); the National Agricultural Research Institute (NARI), Papua New Guinea; the Bureau of Soils and Water Management, Department of Agriculture, the Philippines; and the University of the Philippines Los Baños (UPLB).

Background and justification

Agriculture in Asia and the Pacific has basically been operated by adapting to the Asian monsoon climate, which is stable and periodic on an annual basis and therefore, crop production moves stably and periodically in consequence of the monsoon weather in the region. However, El Nino-related abnormal weather seriously disturbs the fundamental modes of crop cultivation and seriously impedes production of food and other commodities in the affected areas. The weather changes induced by El Nino, namely, a shift of the rainy season, less rain, prolongation of the dry season and high temperatures, have brought serious damage to wide areas of the agricultural sector in the region.

The tremendous impacts of the El Nino phenomenon can be explained by the following aspects. Firstly, it occurs almost simultaneously in many countries of Asia and the Pacific and hence, causes a simultaneous decline in agricultural production in those affected countries. The impacts are additive and create a sudden decline in aggregate production in the region. Secondly, rice, the main staple food in the region, as well as other food crops, are the most sensitive ones to abnormal weather changes. Eventually, the El Nino phenomenon creates food shortages in the affected countries. Thirdly, besides being the largest consuming region, Asia is also the largest rice-producing center in the world. A sharp and sudden decline of rice production in this region could create a shortage of rice supply in the world market and hence, induce a sharp increase in the world rice price. It is well known that the same is also true in the case of CGPRT commodities. Accordingly, a devastative El Nino phenomenon causes global food security problems.

It is a reality that the fundamental infrastructure of agricultural production is still under-developed in the majority of the countries and areas in Asia and the Pacific. In these countries and areas, it is the most urgent subject for agriculture, especially for almost entirely rain-fed upland agriculture where most CGPRT crops are grown, to establish technological and institutional countermeasures to predict, avoid or minimize and recover the damages caused by the region-wide and persistent abnormal weather, like drought.

In the first place, it is extremely important to elucidate real conditions of upland agricultural technologies and farm management and of El Nino-induced weather changes in these countries and areas. Then the analysis of the damage caused by the abnormal weather should be made on the basis of crop and locality-specific characteristics. Socio-economic structure, infrastructure, resources, and farming systems are important determinants of the potential to cope with the damage and hence, are the main focus of this study. Depending on the outcome of the analysis, strategic policies to overcome the damage will be proposed through technological, managerial and administrative tactics.

The impacts of a large-scale El Nino phenomenon are really devastating for those developing countries in the region, which are highly dependent on the domestic agricultural sector for food security, employment and macro-economic performance. A large-scale El Nino phenomenon could create severe food shortages, increase the number of people living in absolute poverty, and induce severe macro-economic depression. The farm households are generally the poorest segment of the national population. While it affects a country as a whole, the impact of the El Nino phenomenon is, however, discriminatory, biased much more severely on the rural economy, farm households in upland areas in particular.

Accordingly, this study focuses on the impacts of El Nino-induced abnormal weather on agricultural production and the rural economy in upland areas. The emphasis on upland areas is based on the empirical observation that the upland areas are generally constituents of the poorest parts in most developing countries. Moreover, upland areas are in the most fragile agroecological zone. By focusing on the development of upland agriculture, this study will also contribute to the global campaign of sustainable development and poverty alleviation in rural areas.

While it is true that most ESCAP member countries in the Asian monsoon region are vulnerable to El Nino-induced abnormal weather and hence deserve comprehensive research, because of the limited funds, this study will focus on five countries only, namely: Indonesia, Malaysia, Papua New Guinea, the Philippines and Thailand. These five countries, are all located in the most El Nino vulnerable area in Southeast Asia and the Pacific subregions and are sufficient for analyzing the impacts of El Nino-induced abnormal weather on upland agriculture and the rural economy in those developing countries of the region.

Objectives

The overall goal of the project is to provide relevant policy recommendations for effective and efficient weather-related risk management to mitigate the damage caused by El Nino-induced abnormal weather on upland agriculture in Asia and the Pacific. The expected outcome is to stabilize upland agriculture for sustainable rural development in less favored areas of the region.

This goal is achieved by fulfilling the following immediate objectives:

1. To collect and analyze data and information on El Nino-related abnormal weather changes, drought in particular, in Asia and the Pacific region and their impacts on regional upland agricultural production, as well as on regional trade;
2. To collect and analyze data and information on abnormal weather-related damage to upland agricultural production in the participating countries;
3. To collect and analyze exact data and information on upland agricultural technologies, resources, infrastructures, institutions, farm management and household economies based on crop and locality-specific characteristics in the participating countries, with a special emphasis on vulnerability and strategies to cope with El Nino-induced agricultural risks;
4. To elucidate and propose institutional or administrative preparedness and schemes to predict El Nino-related abnormal weather changes and upland agricultural risks in the participating countries as well as in the region; and
5. To prepare strategic proposals for technologies, farm management and administrative policies to stabilize upland crop production and the farm economy in the participating countries affected by frequent abnormal weather, drought in particular.

Expected results and impacts

1. The project will result in a clearer understanding of the occurrence, risks and impacts of El Nino-induced abnormal weather on upland agricultural production and the rural economy in the participating countries;

2. Strategic proposals for upland agricultural technologies, farm management and administrative policies, the expected primary outputs of this project, will be valuable for the participating countries to develop and choose operational countermeasures to cope with El Nino-induced abnormal weather;
3. The lessons derived from the experience of the participating countries will be valuable for other ESCAP member countries which are also vulnerable to El Nino-induced abnormal weather;
4. The results of this study may also be a valuable reference for setting up a regional cooperation scheme among ESCAP member countries which share the common problem of high vulnerability to El Nino-induced abnormal weather in upland agriculture; and
5. Implementation of those national and regional collaborative measures to cope with the abnormal weather will contribute to the sustainable development of upland agriculture and poverty alleviation in the participating countries as well as in other ESCAP member countries.

Research activities

The project is being implemented in collaboration with partner institutes of the participating countries. The project leader, in cooperation with the regional advisor, provides country study guidelines (the scope, concepts and methods) and conducts an analytical study on a regional scale.

The country studies are conducted by the respective national experts based on the guidelines. The national experts are encouraged to organize a loose and temporary group or team, with eligible members to effectively conduct the country study. The studies are implemented in two separate phases during the three-year period. The coverage of study subjects in each phase is as follows:

Phase I: National level (August 2000 - May 2001)

1. Historical review and analysis of the general pattern of El Nino-induced abnormal weather changes;
2. Impacts of abnormal weather on agriculture and the rural socio-economy;
3. Factors affecting sensitivity to weather changes and identifying sensitive areas;
4. Institutional preparedness to predict occurrence and effects and to disseminate information; and
5. Policies, institutional arrangements and local facilities to cope with weather related risks.

Phase II: Local/farm level (June 2001 - April 2002)

1. Existing conditions of sensitive arrears;
2. Impacts of weather changes on farm households and the rural community;
3. Farmers’ responses and the recovering process;
4. Potentials and limitations of farmers’ risk management strategies; and
5. Potentials and limitations of institutional support systems.

Publication and dissemination

The Centre publishes country reports at each phase. The joint workshop was held in September 2002 to disseminate and discuss the research results of the project and to exchange the experiences of other research projects and institutional support systems against climatic risk. The integrated report, featuring a synthesis of the country reports, regional study and outcomes of the workshop, is to be published also. An in-country seminar is planned to be held in each participating country to disseminate the research results and country specific policy recommendations.

Summary of preliminary results of country studies

The preliminary results of country studies are summarized by country in Table 1 and 2 below.

Table 1. Approach, scale and scope of the country studies

Country	Approach/methodology/ Data/reference years	Level	Major topics
Indonesia	Structured survey Secondary data Primary data 1997-98	40 farm households in 4 villages of one province	Drought, pests Rice, maize, cassava Changes in cropping pattern Communal rice storage
Malaysia	Production function Trend analysis Secondary data Primary data 1980-99	National State Individual plantations	Rainfall, temperature, air quality Rice, oil palm, rubber, sugar Institutional preparedness
Papua New Guinea	Rapid rural appraisal Structured survey Primary data 1997-98	96 farm households in 6 villages of low/high altitudes, good/poor infrastructures	Drought, frost Sweet potato, yam banana, cassava Wantok system Migration Emergent foreign aid
Philippines	Rapid rural appraisal Structured survey Primary data 1997-98	82 farm households in 4 villages of one municipality	Drought Rice, maize Small water impounding project
Thailand	Production function Structured survey Secondary data Primary data 2001	240 farm households in 2 villages of two provinces	Drought Rice, maize, cassava, sugarcane, Rain water harvest, diversification

Table 2. El Nino impact, damage and mitigation measures

Country	Impact	Damage	Mitigation measures
Indonesia	Rainfall reduction	Area loss followed by pest attack. Upland Rice: serious Maize: middle Cassava: small	Delayed planting, early harvest: not effective. Communal rice storage, livestock sale, diet substitution (rice to cassava): calorie intake no loss
Malaysia	Rainfall reduction Higher temperature Air pollution	Significant yield loss of oil palm. Minor yield loss of rubber and rice.	Risk born by oil palm estate. Irrigation Zero burning
Papua New Guinea	Rainfall reduction Frost	Significant production loss of sweet potato and other staples. Drinking water shortage. Wide spread famine.	Livestock sale Bush foods (yam, taro) Carting drinking water Migration Foreign food aid
Philippines	Rainfall reduction	Significant yield and income loss of rainfed rice	Small water impounding
Thailand	Rainfall reduction	Yield decline of upland rice and maize.	Temporal migration for non-ag. Job. Bank loan. Individual rice storage. Rain water storage for domestic use. Gvt.: seed provision, village fund

Reference

The CGPRT Centre, 1998. Strategic Plan for the CGPRT Centre: Towards the 21st Century.
ESCAP, 1982. Annual Report of ESCAP 1981-82.

ENSO Impacts on Food Crop Production and the Role of CGPRT Crops in Asia and the Pacific

Shigeki Yokoyama[*]

Abstract

To clarify the impacts of El Nino events on production of major food crops in Asia and the Pacific, log linear regression, incorporating a El Nino year dummy variable was conducted. Production variability was measured by percentage deviation from a five-year moving average as trend. ENSO (El Nino Southern Oscillation) sensitivity was measured by correlation coefficient between percentage deviation from the five-year moving average and monthly average of SOI (June to September in the year concerned). Estimated period was 1961 to 2000. Six crops (rice, maize, soybean, groundnut, sweet potato and cassava) and eleven countries (Myanmar, Thailand, Laos, Cambodia, Viet Nam, Malaysia, Indonesia, the Philippines, Australia, New Zealand, and Fiji) were covered. The El Nino event is becoming more frequent as it occurred once in the 1960s, twice in the 1970-1980s and three times in the 1990s. Compared with production loss in non-El Nino years, that in El Nino years was characterized as: 1. Absolute magnitude (7 per cent loss during El Nino vs. 3 per cent loss during non-El Nino); 2. Simultaneity of both yield and area decline (production loss during non-El Nino was mostly caused by yield decline); 3. Single year phenomenon with recovery of production in the following year. Maize was most variable and sensitive to ENSO for both the area harvested and yield, followed by soybean which was significantly sensitive to ENSO in terms of area but not yield. A unique feature of maize is its positive correlation between area harvested and yield. Rice is most stable, while its area harvested is moderately affected by ENSO. Cassava, sweet potato and groundnut were not significantly affected by ENSO, although their production variability was larger than that of rice. Enhancement of the production stability of maize and soybean and diversification of farming systems through incorporating root crops are expected to improve the stability of food crop production in the region.

Introduction

Extreme weather events such as heat waves, cyclones, drought, intense rainfall, tornados, avalanches, thunderstorms and dust storms cause adverse effects widely throughout Asia and the Pacific. The intensity and frequency of these events increased throughout the 20th century (IPCC, 2001). Among others, El Nino-induced drought is a major and common agricultural risk in tropical Asia and the Pacific, especially for upland crops mostly grown under rainfed conditions (World Meteorological Organization, 1999). Establishing technological and institutional countermeasures to predict, avoid, minimize and recover from the damage caused by El Nino-induced drought is urgently required to stabilize rainfed agricultural production, leading to sustainable rural development in less favored areas.

This paper aims to clarify the effects of ENSO (El Nino Southern Oscillation) on food

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crop production in tropical Asia and the Pacific. Firstly, we review the historical occurrence of El Nino events in the last forty years, and measure their impact on cereal production in the region. Secondly, we clarify the characteristics of production loss in El Nino years compared to that of non-El Nino years. Thirdly, we examine production variability and its ENSO sensitivity by major food crops in the region. We conclude with policy implications focusing on roles of upland crops.

Methods and data

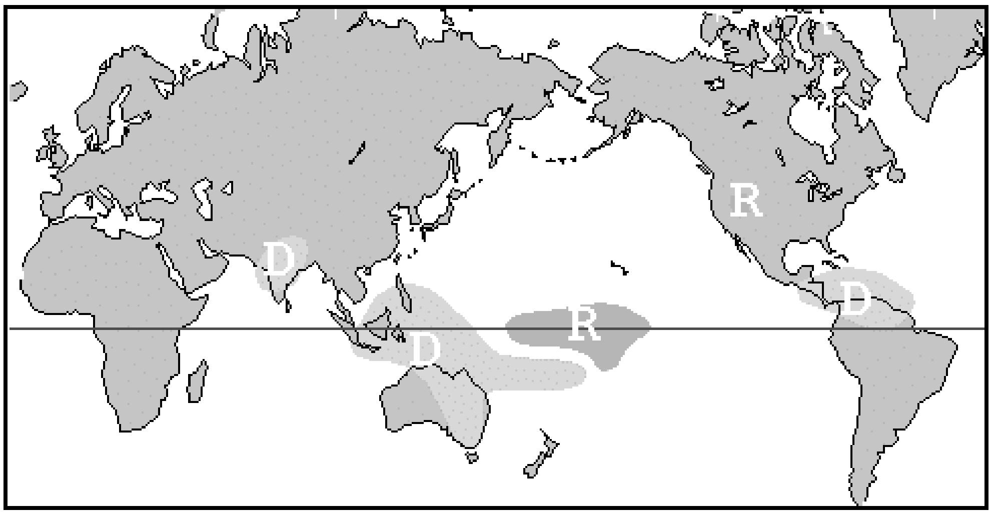
Specification of an El Nino year

The term El Nino (the Christ Child in Spanish) was originally referred to the phenomenon of an annual weak warm sea current from south to north along Peru and Ecuador about Christmas time by the local fishermen in the late 19th century or some time before (Fagan, 1999:27; Glantz, 1996:13). It was known that this abnormal warming disrupted local fish and bird populations. Scientists later showed that the coastal warming is associated with the Pacific basin-wide phenomenon linking atmospheric and oceanic components. As research progresses, the term El Nino covers a wider range of phenomena: 1. The occasional return of unusually warm water in the normally cold water (upwelling) region along the Peruvian coast (ENSO warm event), 2. A Pacific basin-wide increase in both sea surface temperature in the central and/or eastern equatorial Pacific Ocean and in sea level atmospheric pressure in the western Pacific (Southern Oscillation), 3. ENSO (El Nino Southern Oscillation) basin-wide changes in air-sea interaction in the equatorial Pacific region, (Glantz, 1996:16).

The Southern Oscillation is a seesaw like oscillation of sea level air pressure change across the Pacific basin. Southern Oscillation Index (SOI) is the normalized difference in pressure between Tahiti (south-central Pacific) and Darwin (northern Australia) (Tahiti minus Darwin). The combination of El Nino, the oceanic component, and the Southern Oscillation, the atmospheric component, makes up the term ENSO. Negative SOI is associated with warm ENSO and positive with cold ENSO, which is referred to as La Nina (the young girl in Spanish). The ENSO system arouses keen interest for three reasons: it can be modeled, its influence on climate is global, and there is a time lag between climatic consequences (Gommes *et al*., 1998). During April-September, the ENSO warm event has been associated with drought in Indonesia, northern Australia, India and northeastern Latin America, while its expected impacts in October-March are drought in southern Africa, continuing drought in northern Australia and Indonesia, high rainfall in eastern equatorial Africa, the Gulf of Mexico, western equatorial Latin America and southeastern Latin America, and unseasonably warm weather in parts of North America, eastern China, the Korean peninsula and Japan (Figure 1 and 2).

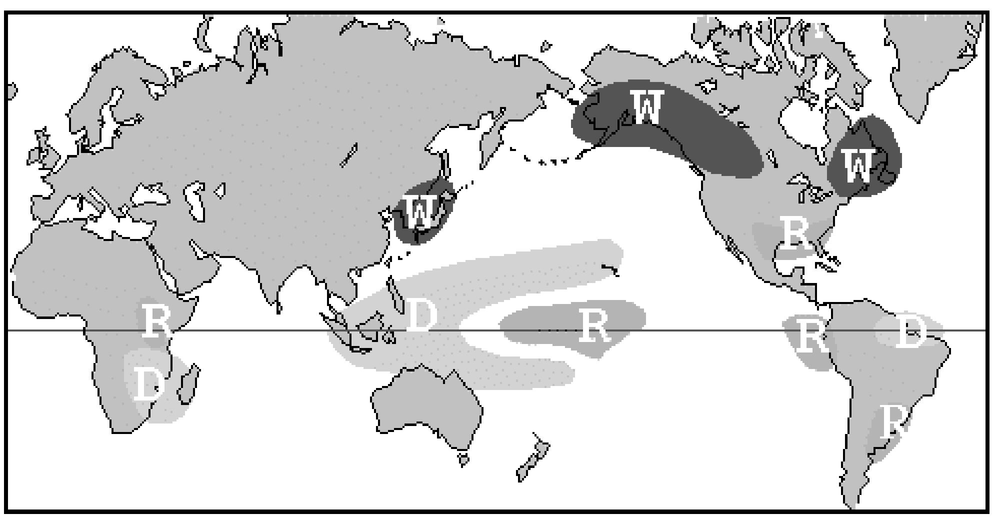
The ENSO event is commonly measured by SOI and sea surface temperature (SST) across the Pacific Ocean. However, due to the variations in timing and geographic patterns of warming, defining El Nino and La Nina universally, agreeable both qualitatively and quantitatively, is difficult (World Meteorological Organization, 1999). A quantitative definition of El Nino, originally proposed by the Japan Meteorological Agency, then modified by the Climate Variability and Predictability (CLIVAR) project, gives five-month running means of SST anomalies in the Nino 3.4 region (5°N-5°S, 170°W-120°W) that exceed 0.4°C for six months or more, based on accepted concepts and designed to be consistent with previous recognized events (Trenberth, 1997). The multivariate ENSO Index (MEI) was devised to measure the strength of ENSO events which is expressed in the first principal component of six observed variables over the tropical Pacific: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C) (Wolter and Timlin, 1993). These two indices are well accepted for overall monitoring ENSO phenomenon. However, if one's interest in ENSO is to a specific part of the world, it is recommended to establish another index to fit one's needs (Trenberth, 1997; comment by Wolter at MEI Web site, 2002).

Figure 1. Climatic impacts of warm ENSO during April to September



D: Drought, R: High rainfall (not necessarily intense).
Source: Gommes *et al*., 1998.

Figure 2. Climatic impacts of warm ENSO during October to March



D: Drought, R: High rainfall (not necessarily intense), W: Abnormally warm.
Source: Gommes *et al*., 1998.

For our study area, southeast Asia and Australia, the SOI is known as a good indicator of rainfall (Podbury *et al*., 1998; Yoshino *et al*., 2000; Nicholls and Beard, 2000; Tawang *et al*., 2002; and Naylor *et al*., 2002). Consistently negative and rapidly falling SOI phase was associated with dry spells (Stone and Auliciems, 1992). Based on this finding, we specified El Nino years as when the annual average of SOI was lower than the standard deviation (-7.28), in the period of 1961-2000, and the annual average of SOI substantially (more than 2.00) declined from that of the previous year. Accordingly, since 1961 we identified eight El Nino years as 1965, 1972, 1977, 1982, 1987, 1991, 1994 and 1997. This specification is highly identical with those of CLIVAR and MEI (Trenberth, 1997; Wolter and Timlin, 1998).

El Nino impact on cereal production

To clarify the impacts of El Nino-induced abnormal weather conditions on total cereal production in the region, we ran simple linear regressions of production, area harvested, and yield against time, incorporating a dummy variable for El Nino years.

Production variability and ENSO sensitivity by crop

Production variability was measured for each crop by percentage deviation from a five-year moving average as trend, assuming no technological progress took place in the five-year period (Gommes, 1998, measured production loss based on seven-year moving maximum). ENSO sensitivity was measured by correlation coefficient between percentage deviation from the 5-year moving average and monthly average of SOI (June to September in concurrent year).

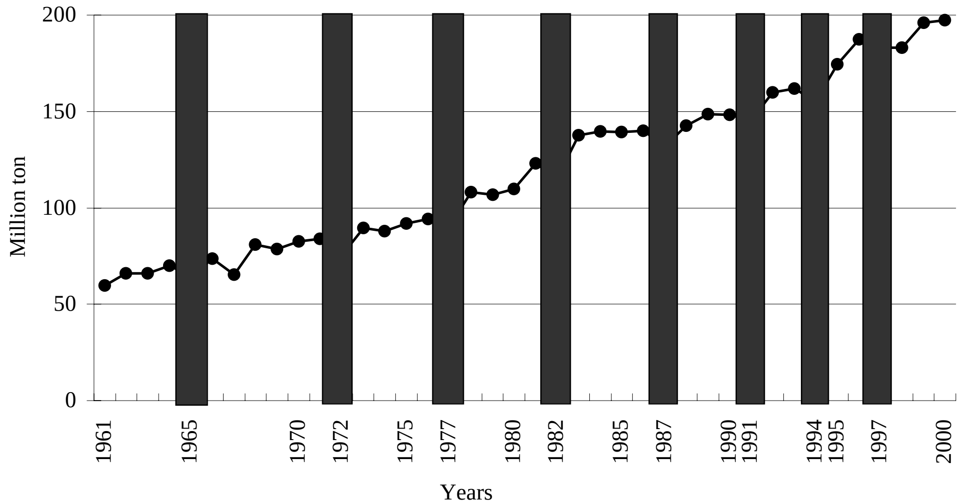
The estimation period was 1961-2000. Analyzed crops were Total Cereals (aggregation of wheat, rice, barley, maize, rye, oats, millet, and sorghum), rice, maize, soybean, groundnut, sweet potato, and cassava. Covered countries were Myanmar, Thailand, Lao People's Democratic Republic, Cambodia, Viet Nam, Malaysia, Indonesia, the Philippines, Australia, New Zealand*, and Fiji (* Not applicable to variability and sensitivity analyses). Data sources were as follows. Production, area harvested, and yield were obtained from FAOSTAT (http://apps.fao.org/). SOI was taken from S.O.I. Archives, Bureau of Meteorology, Australia (http://www.bom.gov.au/climate/current/soihtm1.shtml).

Results

Occurrence of El Nino

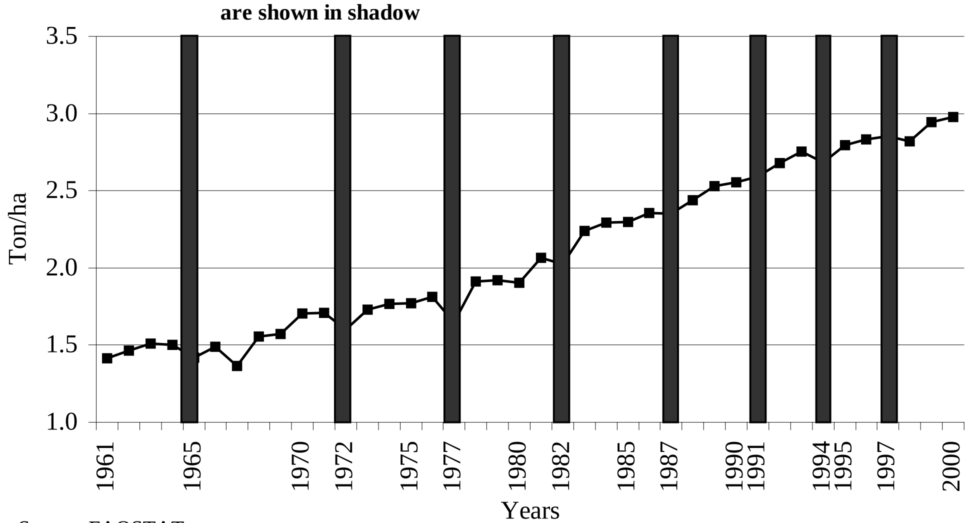
The El Nino event has been increasingly frequent in the last 40 years, as shown by one occurrence in the 1960s, two in the 1970-1980s and three in the 1990s (Figure 3, 4, and 5). This finding is consistent with the well-accepted observations that the characteristics of ENSO, over the second half of the 20^{th} century, may have changed, namely, more El Nino events since the 1970s, with a continuous sequence in the early 1990s and two major events in 1982-83 and 1997-98. It is also suggested that the changed frequency and intensity of recent El Nino events is beyond the expected climate system variability but may be linked to anthropogenic influences (World Meteorological Organization, 1999).

Figure 3. Production of total cereals in the region, 1961-2000. El Nino years are shown in shadow



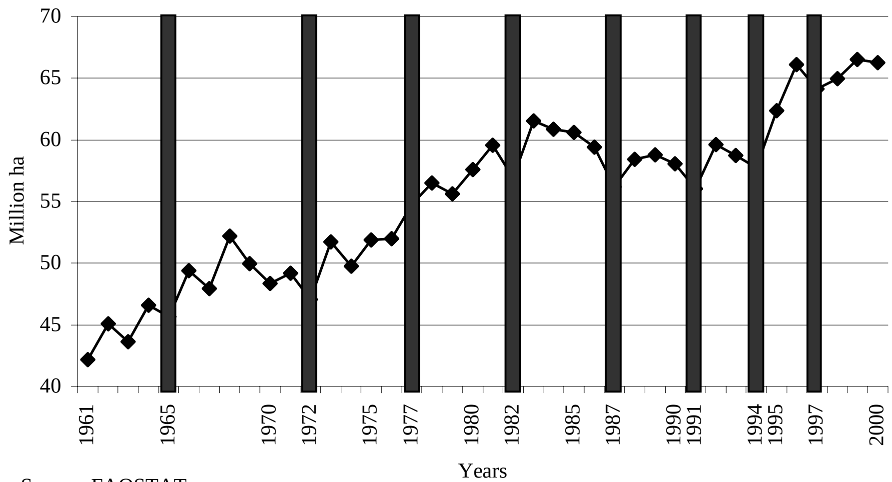
Source: FAOSTAT.

Figure 4. Yield of total cereals in the region, 1961-2000. El Nino years are shown in shadow



Source: FAOSTAT.

Figure 5. Area harvested of total cereals in the region, 1961-2000. El Nino years are shown in shadow



Source: FAOSTAT.

El Nino impact on cereal production

The results of regression analyses are shown in Table 1. All three functions are well fitted with a high value of adjusted R^2. Coefficient of "Year" was significant at the 1 per cent level for the three functions. Coefficient of "El Nino dummy" was significant at the 1 per cent level for production and at the 5 per cent level for area harvested and yield.

As the dependent variable of production and yield functions was transformed into natural log, the coefficient of the independent variable can be directly interpreted as change ratio (Naylor *et al*., 1997). Thus, total cereal production of the region in the period from 1961 to 2000 had grown 3 per cent annually but dropped by 8 per cent in El Nino years. The annual growth rate of its yield was 2 per cent, while in El Nino years it declined by 4 per cent (Table 1).

Table 1. Results of regression analyses, total cereals, in the region, 1961-2000

	Ln Production (ton)	Area harvested (ha)	Ln Yield (t/ha)
Intercept	- 43.12**	-1.02E+9**	-34.33**
	(-32.54) [b]	(-16.73)	(-30.36)
Year	0.0311**	540,911**	0.0212**
	(46.52)	(17.67)	(37.10)
El Nino Dummy [a]	-0.0803**	-232,155*	-0.0401*
	(-4.156)	(-2.624)	(-2.434)
Adjusted R^2	0.98	0.89	0.97
F value	1082.70**	155.892**	689.717**
Durbin-Watson statistic	1.36	0.68	1.00

[a] 1 for 1965, 1972, 1977, 1982, 1987, 1991, 1994 and 1997, and 0 otherwise.

[b] Numbers in parentheses are t-statistics.

** Significant at the 1% level.

* Significant at the 5% level.

Source: Author's calculation.

Characteristics of El Nino-induced production loss

To illustrate the characteristics of the El Nino impact, production loss in El Nino years and that in non-El Nino years was compared. During the period of 1961-2000 we identified 19 cases of reduced production by 1 per cent or more from the trend, namely, 8 El Nino years and 11 non-El Nino years.

Production loss in El Nino years has two distinct features. Firstly, absolute magnitude in El Nino years of 7 per cent on average was significantly larger than that of 3 per cent in non-El Nino years. Secondly, in El Nino years 4 out of 8 cases or 50 per cent, of both area harvested and yield declined simultaneously, while that happened only 18 per cent (2 out of 11) in non-El Nino years (Table 2).

Although the damage was substantial, El Nino production loss was mostly a single year phenomenon with recovery of production in the following year due to the La Nina occurrence up until the late 1980s. However, the cyclical pattern of El Nino and La Nina has become unclear since the early 1990s, resulting in poor recovery or continuous loss (Table 3).

Table 2. Percentage deviation from the trend in production reduction years[1], 1961-2000

El Nino years	Production (%)	Area harvested (%)	Yield (%)
1965*	- 7	- 3	- 4
1972*	- 13	- 7	- 7
1977	- 10	+ 3	- 14
1982	- 2	+ 2	- 4
1987	- 4	- 4	- 0
1991	- 6	- 8	+ 1
1994*	- 9	- 8	- 1
1997*	- 2	- 1	- 2
Average	**- 7**	**- 3**	**- 4**
Non-El Nino years			
1961	- 3	- 7	+ 4
1967	- 11	- 0	- 12
1974*	- 4	- 3	- 1
1975	- 3	- 0	- 3
1976*	- 3	- 1	- 3
1980	- 1	+ 6	- 6
1990	- 1	- 4	+ 2
1993	- 2	- 5	+ 3
1998	- 5	- 0	- 5
1999	- 1	+ 1	- 3
2000	- 4	- 0	- 4
Average	**- 3**	**- 1**	**- 3**

[1] Years in which production reduced by 1 % or more from the trend.
Trend is estimated as ln y = a + bt for production and yield, and: y = a + bt for area harvested.
* Years in which both area and yield declined by 1 % or more.
Source: Author’s calculation.

Table 3. Percentage deviation from trend in the following El Nino years, 1961-2000

	Production (%)	Area harvested (%)	Yield (%)
1966	+ 3	+ 4	- 1
1973	+ 1	+ 2	- 1
1978	+ 4	+ 6	- 2
1983	+14	+ 10	+ 4
1988	+ 1	- 1	+ 2
1992	- 0	- 3	+ 3
1995	- 0	- 1	+ 1
1998	- 5	- 0	- 5
Average	**+ 2.3**	**+ 2.0**	**+ 0.3**

Trend is estimated same as Table 2.
Source: Author’s calculation.

Production variability by crop

The ENSO impact differs by crop, according to its water requirement, dominant production condition (irrigated or rainfed), crop season, applied technology, farmer choice, etc. To clarify the characteristics of individual crops against ENSO, production variability and ENSO sensitivity are measured separately by crop and the results are then synthesized.

Production variability is measured by standard deviation of percentage departure from trend as a 5-year moving average (Table 4). Among the six major food crops, maize was the most variable in production and yield. A unique feature of maize is its positive correlation (0.53) between area harvested and yield which intensifies production variability. Soybean is the second most unstable crop for which variability is mostly explained by area fluctuation. Cassava, sweet potato and groundnut are all moderately variable. Cassava and sweet potato show negative correlation between area and yield, though their absolute value is small. Rice stands most stable, even though the water requirement, 600-1,000 mm during 90-100 days growing period (De Datta, 1981:313-331), is largest among the crops. Rice production stability is attributed to its favorable production condition, as irrigated rice makes up 55 per cent of the world's harvested area and 75 per cent of world rice production (IRRI, 2002).

Table 4 Production variability by crop in the region[1], 1963-1998

	Variability [2]			Correlation [3]
	Production	Area harvested	Yield	Area vs. Yield
Maize	7.7	5.6	3.2	0.53
Soybean	6.8	6.2	2.8	0.03
Cassava	5.1	4.5	3.0	-0.12
Sweet potato	4.7	4.5	2.6	-0.19
Groundnut	4.2	3.1	2.7	0.04
Rice	2.6	1.7	1.7	0.18

[1] Myanmar, Thailand, Laos, Cambodia, Viet Nam, Malaysia, Indonesia, the Philippines, Australia, Fiji.
[2] Standard deviation of percentage departure from the 5-year moving average.
[3] Correlation coefficient of percentage departure from the 5-year moving average.
Source: Author's calculation.

ENSO sensitivity by crop

ENSO sensitivity is measured by correlation coefficient between percentage departure from a 5-year moving average and SOI (monthly average of June to September in concurrent years) (Table 5). Same as is in the case for production variability, maize is the most ENSO sensitive followed by soybean. Maize is sensitive both in its area and yield, while soybean is significantly correlated only in area. Rice is moderately ENSO sensitive in its area, as is soybean, while its production is less sensitive than that of soybean. Sweet potato, groundnut and cassava are not ENSO sensitive, though their production variability is larger than that of rice (Table 4). However, it should be noted that production of sweet potato, which is a staple food in the highlands of New Guinea Island, was substantially damaged in the El Nino years. A series of frosts associated with drought destroyed this root crop, resulting in serious famine (Ballard, 2000 and Bourke, 2000).

Productive variability and ENSO sensitivity is summarized in Table 6. As expected, the more ENSO sensitive, the more variable in production. Exceptions are root crops (cassava and sweet potato) and groundnut. These crops are moderately variable in production but ENSO non-sensitive. The common characteristics of these crops are drought tolerance, especially root crops, and they are widely grown under sub-optimal land and climatic conditions with traditional technologies (Horton, 1988; Wallis and Byth (eds.), 1987). Cassava, known as famine reserve, is cultivated in a substantially wide range of agro-ecological settings at an altitude of sea level to 2,000 masl and under annual rainfall of 500 mm to tropical rainforest. It can withstand 5-month dry periods (Horton, 1988:2). Thus, production variability of these crops is more attributed by the latter characteristic rather than the ENSO impact. However, it should also be noted that their production is not fully represented in the official statistics since they are mainly grown as a second or third crop in a mixed cropping system for home consumption.

Table 5. ENSO sensitivity[1] by crop in the region, 1963-1998

	Production	Area harvested	Yield
Maize	0.78**	0.69**	0.68**
Soybean	0.49**	0.49**	0.11
Rice	0.35*	0.52**	0.02
Sweet potato	0.21	0.17	0.09
Groundnut	0.14	0.19	-0.01
Cassava	-0.01	-0.07	0.09

[1] Correlation between percentage departure from the 5-year moving average and SOI (Jun-Sep in concurrent year).
** Significant at the 1 per cent level.
* Significant at the 5 per cent level.
Source: Author's calculation.

Table 6. Productive variability and ENSO sensitivity by crop in the region

		ENSO sensitivity			
		None	Weak	Moderate	Strong
Production Variability	Large				Maize
	Moderate	Cassava Sweet Potato Groundnut		Soybean	
	Small		Rice		

Compiled from Table 4 and 5.

Summary and conclusions

The El Nino event has been increasingly frequent in the last 40 years. Compared to the production loss in non-El Nino years, that in El Nino years was characterized by: i) absolute magnitude (El Nino years: 7 per cent vs. non-El Nino years: 3 per cent); ii) simultaneity of both yield and area decline (production loss in non-El Nino years was mainly caused by yield decline); and iii) single year phenomenon with recovery of production in the following year.

Among the six major food crops, maize was most sensitive to ENSO for both the area harvested and yield, followed by soybean which was significantly sensitive to ENSO in terms of area but not yield. Rice was weakly affected by ENSO. Cassava, sweet potato and groundnut were not significantly affected by ENSO, though their production variability was larger than that of rice. Enhancement of the production stability of maize and soybean and crop diversification by incorporating root crops may improve stability of food crop production in the region.

Production of legumes and root cops in the region is stagnant or declining despite increasing demand. Roles of these secondary crops are summarized as follows. Legumes are important supplements to a cereal-based diet, a low cost alternative to protein, a supplemental source of green vegetables, animal feed, fuel material (beanstalk and pod), a source of soil nutrients through nitrogen fixation, and a disease control in crop rotation (McWilliams, J.R. and Dillon, J.L., 1987:23-24). Root crops are also known as security food, an important income source for resource poor farmers in marginal areas, cheap food for the urban poor, animal feed, and fuel material (cassava stem) (Scott *et al.*, 2000). Processing and marketing these crops provides job opportunities for the landless and rural women. The gap of root crop yield between the developed and the developing countries remains large, suggesting a high potential of production increase in the latter without area expansion. Prospects for yield increases of root crops appears much greater than those of major cereals, many of which are already trapped on a yield plateau (TAC, 1997). Thus, promotion of legume and root crops contributes to reducing climatic risk of rainfed agriculture, improving food security, and poverty alleviation in a cost effective manner.

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Reference

Ballard, C., 2000. Condemned to repeat history? ENSO-related drought and famine in Irian Jaya, Indonesia, 1997-98. *In* R.H. Grove and J. Chappell (eds.) El Nino: History and crisis, Cambridge, UK: The White Horse Press.

Bourke, R.M., 2000. Impact of the 1997 drought and frosts in Papua New Guinea. *In* Grove, R.H. and Chappell, J. (eds.) El Nino: History and crisis, Cambridge, UK: The White Horse Press.

De Datta, S.K., 1981. Principles and Practices of Rice Production, New York: John Wiley and Sons.

Fagan, B., 1999. Flood, Famines and Emperors, New York: Basic Books.

Glantz, M.H., 1996. Currents of Change: El Nino’s impacts on climate and society, Cambridge, UK Cambridge University Press.

Gommes, R., 1998. Climate-Related Risk in Agriculture. A note prepared for the IPCC Expert Meeting on Risk Management Methods. (http://www.fao.org/waicent/faoinfo/sustdev/EIdirect/agroclim/concepts.htm).

Gommes, R., Bakun, A. and Farmer, G., 1998. An El Nino Primer. (http://www.fao.org/WAICENT/FAOINFO/SUSTDEV/EIdirect/EIan0008.htm).

Horton, D., 1988. Underground crops: Long-term trends in production of roots and tubers, AR, USA: Winrock International Morrilton.

IPCC (Intergovernmental Panel on Climate Change), 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability, Cambridge, UK: Cambridge University Press.

IRRI (International Rice Research Institute), 2002. Rice fact. (http://www.irri.org/Facts.htm#irrigated).

McWilliams, J.R. and Dillon, J.L. 1987. Food legume crop improvement: Progress and constraints. *In* Wallis, E.S. and Byth, D.E. (eds.) Food legume Improvement for Asian Farming Systems. Proceedings of an international workshop, Khon Kaen, Thailand, 1-5 September 1986. Australian Centre for International Agricultural Research.

MEI index (update 3 June 2002). (http://www.cdc.noaa.gov/~kew/MEI/table.html).

Naylor, R., Falcon, W. and Zavaleta, E., 1997. Variability and Growth in Grain Yields, 1950-94: Dose the Record Point to Greater Instability? Population and Development 23(1).

Naylor, R., Falcon, W., Wada, N. and Rochber, D., 2002. Using El Nino Southern Oscillation climatic data to improve food policy planning in Indonesia. Bulletin of Indonesian Economic Studies 38(1).

Nicholls, N. and Beard, G., 2000. The application of El Nino-Southern Oscillation information to seasonal forecasts in Australia. *In* Wilhite, D.A. (ed.). Drought: Volume I A Global Assessment, London and New York: Routledge.

Podbury, T., Sheales, T.C., Hussain, I. and Fisher, B.S., 1998. Use of El Nino climate forecasts in Australia. Amer. J. Agr. Econ. 80(5).

Scott, G.J., Rosegrant, M.W. and Ringler, C., 2000. Roots and Tubers for the 21st Century: Trends, Projections and Policy Options. IFPRI and CIAT, Food, Agriculture, and Environment Discussion Paper 31.

Stone, R. and Auliciems, A., 1992. SOI phase relationship with rainfall in eastern Australia. Int. J. Climatology 12.

Tawang, A., Ahmad, T.A.T. and Abdullah, M.Y., 2002. Stabilization of upland agriculture under El Nino-induced climatic risk: Impact assessment and mitigation measures in Malaysia. Working Paper No. 61, Bogor, Indonesia: CGPRT Centre.

Technically Advisory Committee (TAC), 1997. Report on the inter-centre review of root and tuber crops research in the CGIAR, Washington, D.C: Consultative Group on International Agricultural Research (CGIAR).

Trenberth, K.E., 1997. Definition of El Nino. Bulletin of American Meteorology Society, August 1, 1997.

Wallis, E.S. and Byth, D.E. (eds.), 1987. Food legume improvement for Asian Farming Systems. Proceedings of an international workshop, Khon Kaen, Thailand, 1-5 September 1986. Australian Centre for International Agricultural Research.

Wolter, K. and Timlin, M.S., 1993. Monitoring ENSO in COADS with a seasonally adjusted principal component index. *In* Norman, Proceedings of the 17th Climate Diagnostics Workshop, p. 52-57. OK, NOAA/N MC/CAC, NSSL, Oklahoma Clim. Survey, CIMMS and the School of Meteor, Univ. of Oklahoma.

Wolter, K. and Timlin, M.S., 1998. Measuring the strength of ENSO: How dose 1997/98 rank? Weather, 53:315-324.

World Meteorological Organization, 1999. The 1997-1998 El Nino Event: A Scientific and Technical Retrospective.

Yoshino, M., Urushibara, K. and Suratman, W., 2000. Agricultural production and climate change in Indonesia. Global Environ. Res. 3(2).

Impact of El Nino 1997/98 and Mitigation Measures: Case of Lampung-Indonesia

Bambang Irawan[*]

Introduction

Since the 1980s, El Nino events, which cause abnormal weather changes, were recognized as one of the causes of agricultural production failure. El Nino-related abnormal weather, seriously disturbs the fundamental modes of crop cultivation and damages the production of food and other commodities in the affected areas. The El Nino phenomenon has tended to increase in its frequency of occurrence, magnitude, duration and irregularity in recent years and hence, it is now the most dangerous factor in agricultural production. Accordingly, it is a most urgent subject for agriculture, especially for rainfed upland agriculture, where most CGPRT crops are grown, to establish institutional countermeasures in order to minimize and recover from the damage.

Firstly, it is extremely important to elucidate the impact of El Nino on food production, especially in vulnerable areas. Rural economic structure, infrastructures, resources and farming systems in vulnerable areas will be among the most important determinants of social potential to cope with the damage and hence, will be a main focus of the study. Secondly, it is important to clarify consumption impact, mitigation strategies to cope with the damage at farm and household levels and factors or constraints related to the realization of the strategy. Depending upon the outcome of the analysis, strategic policies to overcome El Nino problems will be proposed.

Study region and data

The study was conducted in the province of Lampung, located in the southern part of Sumatera island. Lampung is one of the provinces that experienced a high rate of food area drop due to the 1997/98 El Nino, which was 18.4 per cent or 3 times the area drop rate on the national level (Irawan, 2002). The province was one of the major food producers in Indonesia, particularly for food crops cultivated in upland areas or dryland areas such as CGPRT crops. The national production share of Lampung was about 12 per cent for dryland rice, 10 per cent for cassava and 7 per cent for maize and soybean. On Sumatera island, where the province of Lampung is located, Lampung has an important role in maize and cassava production, it contributes about 69 per cent and 66 per cent respectively to total production. The province also has an important role in the production of soybean and dryland rice with production shares of 38 per cent and 30 per cent respectively.

Historical secondary data from various publications and official reports of local government institutions were used in the study. Primary data, from indepth studies in 4 selected villages of kecamatan Gunung Sugih in the district of Lampung Tengah, was also applied. As many as 40 farmers in the villages were selected to collect the data and qualitative information

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related to El Nino 1997/98. The selected farmers were those with a good recollection, since explaining an event that happened 5 years ago is not always a simple task. The collected primary data consists of three groups of information: (1) Climate conditions and other related parameters during El Nino events; (2) Impact of El Nino on cultural practices, agricultural production and staple food consumption; and (3) Mitigation applied to reduce production failure and food problems induced.

Impact of the 1997/98 El Nino on the study area

Impact assessment of El Nino 1997/98 on agricultural activities was conducted for two scopes of study: province level (province of Lampung) and household level (kecamatan Guning Sugih). The three types of impact evaluated for the province level are: (a) impact on rainfall, (b) impact on food crop area, and (c) impact on drought and pest disasters. Analysis at the household level was conducted for: (a) changes of cropping pattern, production and yield of crops cultivated by the farmer, (b) impact on staple food consumption, (c) coping strategies applied by the farmer.

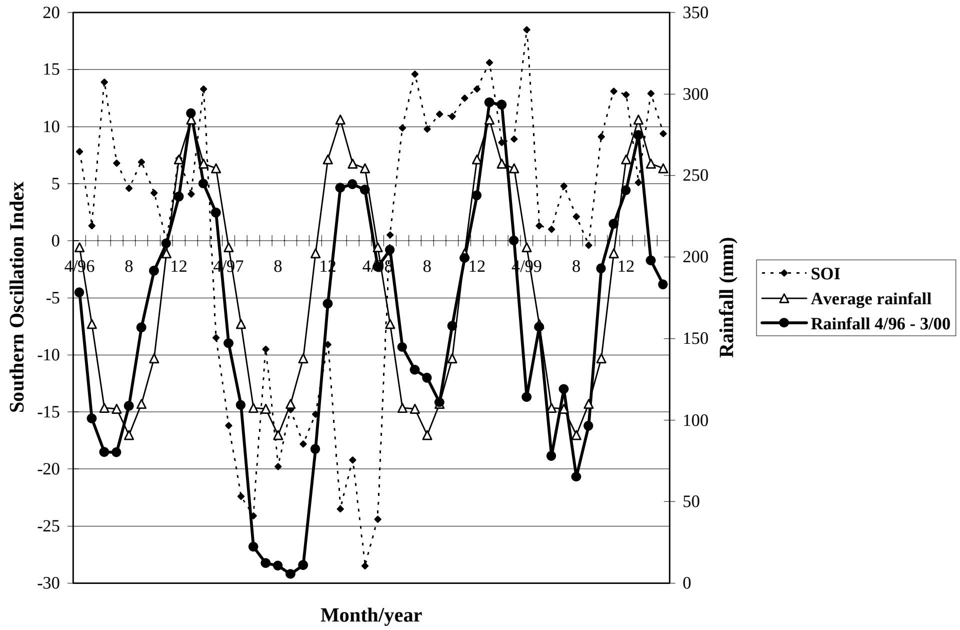
Impact on rainfall

The El Nino event in 1997/98 is often interpreted as the biggest one that century. Meteorologically, the El Nino event was shown by a large negative SOI (Southern Oscillation Index), which is usually followed by a decrease in rainfall. To understand the impact of El Nino on rainfall in Lampung, daily rainfall data from 1977-2000 was collected from Dinas Pengairan Pekerjaan Umum, Propinsi Lampung (Public Works). In total, 75 rainfall stations exist in Lampung but only 46 data sets could be analyzed because of incomplete data, particularly for new stations constructed during the last five years. The analyzed rainfall stations were distributed in 8 districts of Lampung with 3-12 stations per district.

Analysis of the El Nino impact on rainfall was undertaken by comparing seasonal rainfall (dry season and wet season) in 1997 and 1998 compared to the average rainfall of each station, expressed as a percentage. The period of analyzed average rainfall data was different for some stations due to incomplete data, but at least 10 years data from 1990-2000, was used. In general, the dry season in Lampung occurs between April - September and the wet season in October - March. Following this rainfall pattern the wet season of 1997 covered the period of October of 1996 - March of 1997 and the dry season of 1997 covered the period of April of 1997 - September of 1997.

Figure 1 shows the evolution of SOI values, average rainfall and actual rainfall in Lampung for April 1996 - March 2000. From this figure, it is clear that a large negative SOI occurred from February 1997 until April 1998, ranging from -8.5 to -28.5. This means that the El Nino of 1997/98 occurred during this period. In other words, El Nino covered some wet season months of 1997 (February of 1997 and March of 1997) and all months of the dry season of 1997 and wet season of 1998.

Figure 1. Relation between Southern Oscillation Index (SOI) and rainfall in Lampung, April 1996 - March 2000



Source: SOI: Australian Bureau of Meteorology.
Rainfall: Dinas Pengairan Pekerjaan Umum, Propinsi Lampung.

In the case of El Nino or a large negative SOI, rainfall in Lampung tends to decrease compared with the average. The largest rainfall decrease occurred in the dry season of 1997, this result was observed at all stations analyzed, with the rainfall decrease ranging from -41.1 per cent to -82.5 per cent (Table 1). On average, of all the stations analyzed, the rainfall decrease was larger in the dry season of 1997 (-59.1 per cent) than in the wet season of 1998 (-28.1 per cent) even though the negative SOI values were higher during the wet season of 1998. The results are consistent with results obtained in previous work by Yoshino *et al*. (1999). This implies that the El Nino impact on rainfall was not only dependant on magnitude (indicated by large negative SOI) but also influenced by the date of occurrence, during the wet season or dry season. The impact also depends on the length of the period of occurrence of El Nino. This situation was indicated by relatively stable rainfall in the wet season of 1996 (rainfall change only 1 per cent) even though El Nino occurred during two months out of six during the wet season of 1996.

Table 1. Rainfall decrease due to El Nino 1997/98, by rainfall station and by season, in Lampung

		Average rainfall (mm)			Rainfall decrease compared with average rainfall (%)					
					1997			1998		
Station	Alti-tude (m)	Wet season	Dry season	All season	Wet season	Dry season	All season	Wet season	Dry season	All season
Bendungan Argoguruh	52	1,332	581	1,912	-10.8	-45.2	-21.2	-35.6	46.7	-10.6
Gunung Batu	300	1,207	637	1,844	-7.7	-57.3	-24.8	-34.6	-1.1	-23.0
Jati Baru/T. Bintang	65	1,074	724	1,798	27.2	-55.1	-5.9	-25.1	37.8	0.3
Sukajaya-Kedondong	157	1,116	547	1,662	-8.7	-68.3	-28.3	-36.3	-18.8	-30.6
Ketibung	35	1,375	722	2,096	-10.4	-60.6	-27.7	-32.0	31.1	-10.3
Penengahan	45	1,057	673	1,730	0.1	-74.7	-29.1	-39.8	-3.6	-25.7
Air Naningan	385	1,233	866	2,099	-7.5	-73.3	-34.7	-5.7	25.2	7.0
Banjar Agung	165	1,086	577	1,663	-7.9	-63.9	-27.3	-51.8	-29.1	-43.9
Banyuwangi/Suko	120	1,268	685	1,953	1.5	-69.6	-23.4	-36.1	39.6	-9.5
Gisting	560	1,243	967	2,209	12.2	-65.8	-21.9	-5.9	-21.7	-12.8
Gunung Sari	720	1,533	843	2,377	3.1	-71.4	-23.3	-29.2	25.0	-10.0
Kunyir	435	1,394	751	2,145	9.3	-69.8	-18.4	-22.5	18.6	-8.1
Pematang Nebak	430	1,033	587	1,619	23.4	-51.6	-3.7	-22.7	-2.5	-15.4
Pringsewu	100	1,193	638	1,831	2.0	-66.2	-21.8	-26.5	47.7	-0.6
Wonosobo/S. Betik	30	1,116	770	1,886	16.8	-73.3	-20.0	-0.9	-18.9	-8.3
Srikaton/ Srikuncoro	30	1,387	1,087	2,474	-10.9	-82.1	-42.2	-22.7	-14.2	-19.0
Way Harong Toto	370	1,558	865	2,423	1.1	-51.9	-17.8	-12.2	23.9	0.7
Wonokriyo/G. Rejo	65	1,218	722	1,940	-1.4	-59.6	-23.0	-30.5	21.7	-11.1
Metro DPU	58	960	495	1,454	4.4	-46.1	-12.8	-13.0	44.5	6.6
Bumi Kencana	48	1,167	752	1,919	5.9	-44.2	-13.7	-12.9	45.9	10.1
Komering Putih	40	1,271	611	1,883	4.2	-56.2	-15.4	-16.7	34.2	-0.2
Negeri Kepayungan	115	1,273	628	1,901	-7.7	-35.4	-16.9	-20.5	37.4	-1.4
Sindang Asri	120	1,554	844	2,398	-4.6	-55.8	-22.6	-30.7	6.3	-17.7
Bukit Kemuning	310	1,273	752	2,024	8.4	-45.4	-11.6	-11.2	37.0	6.7
Gedung R.S. Utara	46	1,391	731	2,123	-7.0	-57.6	-24.4	-18.8	33.7	-0.7
Ketapang	50	1,972	1,208	3,180	-13.6	-77.6	-38.0	-30.8	-10.0	-22.9
Kotabumi	40	1,153	514	1,667	12.6	-44.2	-4.9	-25.6	56.9	-0.2
Pekurun	70	1,919	1,087	3,006	-21.8	-52.9	-33.0	-40.9	-9.0	-29.4
Daya Murni	25	1,193	616	1,808	2.5	-61.4	-19.2	-32.6	44.1	-6.5
Gedung Ratu	12	1,253	577	1,830	12.3	-43.4	-5.3	-57.2	16.7	-33.9
Menggala	15	1,372	587	1,959	3.4	-42.7	-10.4	-24.7	94.3	11.0
Purwajaya Unit I	30	1,700	665	2,365	-0.8	-45.4	-13.3	-51.2	33.7	-27.3
Sidoharjo G. Aji	9	846	447	1,294	5.5	-64.8	-18.8	-43.6	43.8	-13.4
Air Itam	806	1,596	985	2,582	-3.3	-52.9	-22.2	-22.0	12.0	-9.0
Bungin	810	1,550	987	2,537	-11.2	-71.7	-34.7	-22.6	26.1	-3.7
Dusun Kenali	820	1,780	1,108	2,887	9.2	-64.3	-19.0	-41.9	-17.7	-32.6
Gedung Cahya.K.	12	2,416	1,643	4,059	-8.8	-74.2	-35.3	-46.7	-8.6	-31.3
Kebun Tebu	825	1,610	926	2,536	-2.0	-61.4	-23.7	-22.3	-9.9	-17.8
Rawa Bebek	812	1,916	914	2,830	-22.4	-82.5	-41.8	-40.9	19.3	-21.4
Sekincau	1,000	1,388	852	2,240	17.6	-58.1	-11.2	-16.8	37.3	3.8
Reno Basuki	20	1,449	703	2,152	3.3	-46.1	-12.8	-34.2	34.1	-11.8
Sukadana	23	1,792	784	2,577	-1.5	-41.1	-13.5	-23.1	49.5	-1.0
Way Jepara	22	1,439	777	2,216	3.2	-61.9	-19.6	-50.4	34.9	-20.5
Baradatu	120	1,003	482	1,485	-3.5	-52.5	-19.4	-15.1	21.4	-3.3
Blambangan Umpu	110	1,758	920	2,678	11.3	-67.8	-15.9	-30.2	7.6	-17.2
Tahmi Lumut	275	1,799	1,048	2,846	17.4	-53.3	-8.6	-26.3	3.9	-15.2
	Average	**1,396**	**780**	**2,176**	**1.0**	**-59.1**	**-20.7**	**-28.1**	**20.2**	**-11.5**

Note:
(1) Average rainfall in 1980-2000.
(2) Wet season of 1997 = (October of 1996 - March of 1997); Dry season of 1997 = (April of 1997 - September of 1997).
Source : Dinas Pengairan Pekerjaan Umum. Propinsi Lampung.

The large rainfall decrease in the dry season of 1997 (more than 60 per cent) particularly affected three districts of Lampung, namely, Lampung Selatan, Tanggamus and Lampung Barat (Table 2). A similar situation also happened for the wet season of 1998. This reveals that a lack of rainfall induced by El Nino, tends to be concentrated in certain regions with specific geographic characteristics. Table 2 shows that the rainfall decrease was relatively high in regions of high altitude or in other words, the higher the altitude of a region, the higher the decrease in rainfall caused by El Nino. These regions with higher altitudes are generally dryland or upland regions where most CGPRT crops are grown.

Table 2. Rainfall decrease due to El Nino 1997/98, by district and by altitude, in Lampung

	Average rainfall (mm)			Rainfall decrease compared with average rainfall (%)					
				1997			1998		
District or altitude	Wet season	Dry season	All season	Wet season	Dry season	All season	Wet season	Dry season	All season
District									
Lampung Selatan	1,193	647	1,840	-1.7	-60.2	-22.8	-33.9	15.4	-16.7
Tanggamus	1,272	780	2,052	3.5	-66.5	-23.1	-22.2	9.6	-10.9
Lampung Tengah	1,245	666	1,911	0.5	-47.5	-16.3	-18.8	33.7	-0.5
Lampung Utara	1,541	858	2,400	-4.3	-55.6	-22.4	-25.5	21.7	-9.3
Tulang Bawang	1,273	578	1,851	4.6	-51.5	-13.4	-41.9	46.5	-14.0
Lampung Barat	1,751	1,059	2,810	-3.0	-66.4	-26.9	-30.5	8.3	-16.0
Lampung Timur	1,560	755	2,315	1.7	-49.7	-15.3	-35.9	39.5	-11.1
Way Kanan	1,520	817	2,336	8.4	-57.9	-14.6	-23.9	11.0	-11.9
Altitude									
<200	1,358	735	2,093	-0.1	-57.7	-20.5	-30.9	24.2	-12.3
200-600 m	1,342	809	2,151	7.1	-58.6	-17.7	-17.7	10.4	-7.5
>600 m	1,625	945	2,570	-1.3	-66.0	-25.1	-28.0	13.1	-13.0

Note:
(1) Average rainfall in 1980-2000.
(2) Wet season of 1997 = (October of 1996 - March of 1997); Dry season of 1997 = (April of 1997 - September of 1997).
Source : Dinas Pengairan Pekerjaan Umum. Propinsi Lampung.

Impact on food crop area

Quantification of losses due to bad climate of a given year, could be accomplished by comparing the expected production under normal conditions to actual production during the unfavorable climate. The production difference between those climate conditions reveals the magnitude of bad climate impact on the level of production. If climate variability is assumed as an exogenous factor in a production system, then the expected production of a given region will be the function of price and level of technology. Under this assumption, expected production can be estimated using parameters of production resulting from time series data analysis. This approach was used by Mukhopadhyay (1974). A similar method was also utilized by Gomez (1998), adopting production trend analysis based on a 7-year-moving maximum production, while, instead of a moving maximum production, Yoshino *et al*. (1999) used a 4-year-production means as the base in estimating the expected production.

For further analysis on the effect of weather variability on food crop area in Lampung, the “3-year-moving average” method was applied to food area time series data from 1975 - 2001. During the period, 6 cases of El Nino occurred, 1977, 1982, 1987, 1991, 1994 and 1997 and 2 cases of La Nina in 1988 and 1999. In this context, El Nino was assumed to occur if the value of negative extreme SOI (less than -10) occurred for 4 months successively in a year. A similar assumption is applied to identify a La Nina year, which is one where the value of extreme positive SOI (higher than 10) occurres for 4 months in the respective year.

Table 3 shows that the percentage of area losses from weather variability was higher during an El Nino event than normal climate conditions. Under a normal climate, food crop area in Lampung is around 0.4-2.2 per cent lower or higher than the expected norm. During El Nino years, actual harvested area was generally lower than expected. The highest area drop (-28.4 per cent) occurred to dryland rice, since it is not resistant to water insufficiency. Whereas the impact of El Nino on wetland rice was relatively low (-2.2 per cent) due to the support of irrigation networks on wetland rice crops.

Table 3. Area change compared to the moving average of food crops during an El Nino and La Nina episode in Lampung

Variable	El Nino			La Nina			Normal		
Season	Dry season	Wet season	All season	Dry season	Wet season	All season	Dry season	Wet season	All season
Period of cultivation	Apr-Sept	Oct-Mar	Apr-Mar	Apr-Sept	Oct-Mar	Apr-Mar	Apr-Sept	Oct-Mar	Apr-Mar
Average SOI	-15.0	-16.7	-15.7	n.c	12.1	12.1	1.3	-1.8	-0.2
Number of months under extreme SOI	4.57	4.60	4.58	n.c	4.00	4.00	1.41	0.62	1.03
Area change (%)									
Wetland rice	-2.5	-2.0	-2.2	n.c	14.2	14.2	0.7	2.2	0.7
Dryland rice	-33.4	-21.5	-28.4	n.c	9.7	9.7	1.4	1.9	0.3
Maize	-6.1	-5.3	-5.8	n.c	0.9	0.9	1.7	1.3	0.1
Cassava	-0.6	-1.9	-1.1	n.c	2.7	2.7	0.9	0.4	0.7
Groundnut	-7.3	-12.5	-9.5	n.c	7.2	7.2	2.2	2.1	0.1
Sweet potato	-4.0	-17.1	-9.5	n.c	7.4	7.4	1.4	0.9	1.1
Soybean	-12.0	-7.6	-10.2	n.c	3.7	3.7	1.5	1.0	0.3

n.c = no case.
El Nino years: 1976/77, 1982/83, 1986/87, 1990/91, 1994/95, 1997/98.
La Nina years: 1988/89, 1998/99.
Source: Central Bureau of Statistics, Lampung.

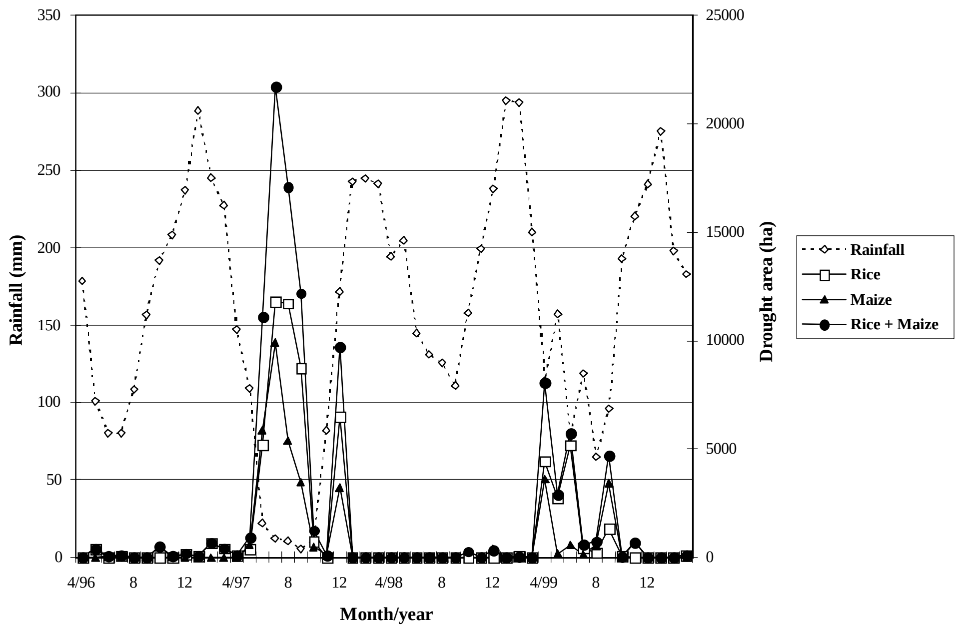
Drought induced by El Nino had little impact on cassava because of its high tolerance to water restriction. A relatively large area decrease occurred with soybean (-10.2 per cent) since soybean is relatively sensitive to water restriction. The same reason might be valid for groundnut and sweet potato with area decreases of -9.5 per cent each. On the contrary, an increase of all food crop areas occurred in the case of La Nina. This result is consistent with research conducted by Yoshino *et al.* (1999) which revealed that food crop production in Indonesia was inclined to increase during La Nina and decrease during El Nino.

Impact on drought disaster

Drought or water insufficiency due to a decrease in rainfall is a common result of El Nino. Balai Proteksi Tanaman Pangan dan Hortikultura in the province of Lampung (Office for Protection of Food crops and Hortuculture) is the agricultural institution which monitors the area of food crops that suffer from drought, pests, floods and other natural disasters. All information regarding drought and pest attacks are compiled and presented in “Laporan Musiman” or seasonal report. However, not all food crops are monitored. Rice and maize are the major concern for drought cases, while for pest cases the report also covered soybean.

Figure 2 shows the evolution of rainfall and the areas of rice and maize cultivations in Lampung suffering from drought for April 1996 - March 2000. From this figure it is clear that a large area suffered from drought between May of 1997 to January of 1998 when rainfall levels drastically dropped. This was during the period of El Nino 1997/98 which covered 14 months from February of 1997 to April of 1998. Due to water insufficiency, the area of rice and maize that suffered from drought augmented in May of 1997, reaching maximum values in July or August of 1997 and ending in October or November of 1997.

Figure 2. Monthly rainfall and area that suffered from drought of rice and maize cultivations in Lampung, April 1996 - March 2000



Source: Provincial Bureau of Statistics, Lampung.

No drought was reported in October and November of 1997 because all rice and maize crops grown in the dry season of 1997 had been harvested in this period. Drought returned again in December of 1997 when farmers had planted their wet season crop of 1997/98, which is generally planted after harvesting the dry season crop.

During the 48 months of April 1996 - March 2000 or 8 periods of cultivation, the area of rice and maize that suffered from drought was respectively 61.621 ha and 39.454 ha, or in total about 101,000 ha (Table 4). About 74 per cent of total drought cases were recorded in May of 1997-April of 1998, or during the El Nino of 1997/98. This reveals that El Nino tends to cause drought disaster due to water insufficiency. Monthly rainfall during this period decreased by about 50 per cent compared with the average rainfall over a long period. A particularly high rainfall decrease was observed in June-October 1997 (dry season) where the monthly rainfall was only 6-22 mm per month or an 80 - 95 per cent decrease compared with average rainfall.

Most of the drought cases of 1997/98 occurred in the dry season of 1997 both for rice and maize. The area of rice farming in the dry season of 1997 that suffered from drought was 37.967 ha while it was 25.209 ha for maize farming. Drought cases also occurred in the wet season of 1997/98 but to a lesser degree, covering 7.251 ha of rice farming and 3.856 ha of maize farming. Thus, the total area of rice and maize that suffered from the drought induced by El Nino 1997/98 was 45.218 ha and 29.065 ha respectively.

Table 4. Seasonal area of rice and maize cultivation in Lampung that suffered from drought, dry season of 1996 to wet season of 1999

Area	Dry-1996	Wet-1996/97	Dry-1997	Wet-1997/98	Dry-1998	Wet-1998/99	Dry-1999	Wet-1999/2000
Area suffered from drought (ha)								
Rice	485	1,308	37,967	7251	10	61	14,393	146
Maize	100	523	25,209	3856	0	637	8,425	704
Total	585	1,831	63,176	11,107	10	698	22,818	850
Area completely damaged by drought								
a. Coverage area (ha)								
Rice	176	419	9,750	307	0	5	1,493	3
Maize	19	10	12,650	502	0	270	170	0
Total	195	429	22,400	809	0	275	1,663	3
b. Percentage to total area suffered (%)								
Rice	36.3	32.0	25.7	4.2	0.0	8.2	10.4	2.1
Maize	19.0	1.9	50.2	13.0	0.0	42.4	2.0	0.0
Total	33.3	23.4	35.5	7.3	0.0	39.4	7.3	0.4

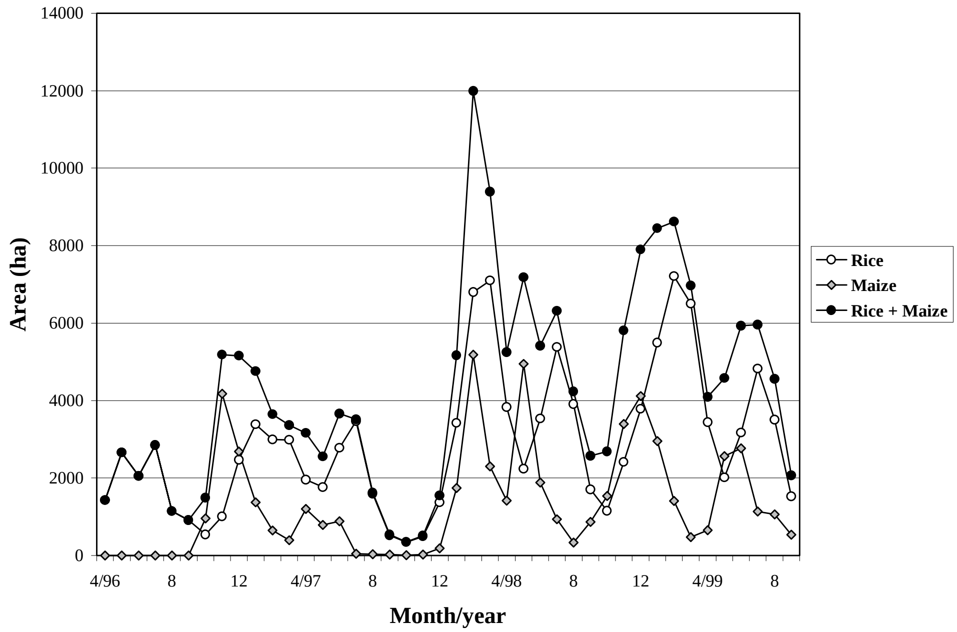
Note:
(1) Wet-1996/97 : wet season of 1997 (October of 1996 to March of 1997).
(2) Dry-1997 : dry season of 1997 (April 1997 to September of 1997).
Source: Balai Proteksi Tanaman Pangan dan Hortikultura, Propinsi Lampung. Laporan Musiman, musim tanam 1996 - musim tanam 1999/2000.

Although the area that suffered from drought was larger for rice farming than maize farming, the area completely damaged/destroyed by drought (or ‘puso’ area) was higher for maize farming. In the dry season of 1997 the ‘puso’ area for maize was 12,650 ha or 50.2 per cent of the total area that suffered, while for rice it was 9.750 ha or 25.7 per cent. The higher rate or percentage of ‘puso’ area of maize compared with rice, indicates that maize farming in Lampung was more sensitive to drought disaster than rice farming. This is because most rice farming in Lampung is wetland rice farming which is cultivated in irrigated areas (sawah land) while maize farming is generally cultivated in dryland areas. In general, water is more available on irrigated land so it is reasonable that the drought impact was lower for rice farming than for maize farming.

Impact on pest disaster

Figure 3 shows the rice and maize areas that suffered from pest attacks sharply decreased in July-December 1997 (dry season of 1997). The increase in pest attacks was observed in January of 1998 and reached a maximum in February of 1998 where the total area that suffered from pests was around 12,000 ha or 3.3 times higher than that in February of 1997 (before the El Nino event). The high pest disturbance continued throughout 1998 and reached a second peak in February of 1999. It covered around 8.600 ha or 2.3 times higher than the area attacked in February of 1997. After that, pest attacks tended to decrease in the following months.

Figure 3. Area that suffered from pest and drought per month for rice and maize in Lampung, April of 1996 - September of 1999



Source: Provincial Bureau of Statistics, Lampung.

The previous evolution of rice and maize crops that suffered from pests shows that during the long drought period of 1997 pest disturbances decreased sharply. However, after that period, during the wet season of 1997/98, pest attacks tended to rise rapidly. The increase in pest attacks occurred during 3 planting periods, the wet season of 1997/98, the dry season of 1998 and the wet season of 1998/99. The coverage area that suffered from pest attacks during the three seasons were respectively 19,505 ha, 25,544 ha and 26,562 ha for rice and 9,351 ha, 10,380 ha, 13,853 ha for maize (Table 5). Soybean also suffered from increasing pest attacks, with a lower coverage area, ranging from 1,026 ha to 1,523 ha per season.

Among the 38 pests to rice cultivation and 28 pests to maize farming, locust and mouse are the major pests which steeply increased. A particularly high increase of locust attacks occurred in the wet season 1997/98 with rice area coverage of about 3,000 ha or more than 30 times higher than the situation of the three previous seasons, from the dry season of 1996 until the dry season of 1997. Locust attacks augmented in the dry season of 1998 with a coverage area of 4,960 ha, then steeply decreased the following seasons (wet season of 1998/99 until wet season of 1999/2000). A similar pattern of locust attacks also occurred for maize cultivation. Figure 4, shows that a very large area suffered from locust attacks in February of 1998 for maize crops and in March 1998 for rice crops.

The evolution of mouse attacks was different to locust, the high increase in the area that suffered from mouse attacks was later than locust, it started in June 1998, during the dry season (Table 5). Total rice area that suffered from mouse attacks in the dry season of 1998 was around 4,900 ha or 3 times higher than the situation in the wet season of 1997/98. The high amount of mouse attacks continued until the dry season of 1999, in other words, 3 seasons of rice cultivation were attacked by a high population of mice or one season more than was the case of locust, which covered 2 seasons of cultivation. As indicated in Table 5, seasonal patterns of mouse attacks were relatively similar for both rice and maize cultivations.

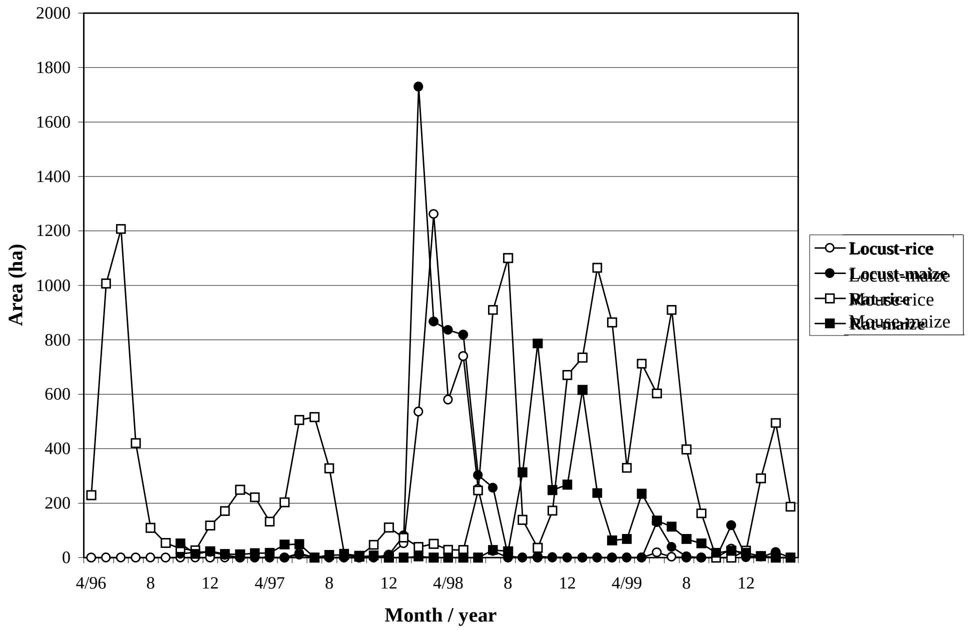
In general, mouse attacks caused greater crop damage to rice than maize, the opposite is true for locust attacks. During 3 cultivation periods of rice (wet season of 1997/98 to wet season of 1998/99) when the increase of pest attacks occurred, total rice area completely damaged (or 'puso' area) due to locust was 734 ha or 8.8 per cent of the area that suffered from locust, while, for the case of mouse attacks, they were respectively 1,285 ha and 9.2 per cent. In the case of maize, for the same seasons, locust attacks caused 'puso' area of 3,495 ha or 30.4 per cent area suffered, while for mouse attacks it was only 149 ha or 4.5 per cent area suffered.

Table 5. Area that suffered from locust, mouse and other pests in Lampung, dry season of 1996 - wet season of 1999/2000

Pest	Season							
	Dry-1996	Wet-1996/97	Dry-1997	Wet-1997/98	Dry-1998	Wet-1998/99	Dry-1999	Wet-1999/2000
Rice area suffered (ha)								
Locust	94	3	80	2,962	4,960	397	296	220
Mouse	5,041	1,725	2,661	676	4,903	8,664	7,341	3,484
All pests	11,464	13,154	10,966	19,505	25,544	26,562	19,114	15,758
Rice area completely damaged or 'puso' (ha)								
Locust	0	0	0	2	458	274	67	35
Mouse	335	1	7	0	789	496	1,705	232
All pests	354	85	17	13	1,595	789	1,957	306
Percentage of area damaged/area suffered (%)								
Locust	0.0	0.0	0.0	0.1	9.2	69.0	22.6	15.9
Mouse	6.6	0.1	0.3	0.0	16.1	5.7	23.2	6.7
All pests	3.1	0.6	0.2	0.1	6.2	3.0	10.2	1.9
Maize area suffered (ha)								
Locust	118	257	29	2,568	8,270	654	1,594	1,137
Mouse	1,474	146	424	13	473	2,792	2,475	131
All pests	2,740	14,255	2,974	9,351	10,380	13,853	5,870	3,750
Maize area completely damaged or 'puso' (ha)								
Locust	8	45	0	532	2,658	305	486	443
Mouse	42	0	0	0	15	134	246	0
All pests	50	1,492	12	532	2,719	768	786	457
Percentage of area damaged/area suffered (%)								
Locust	6.8	17.5	0.0	20.7	32.1	46.6	30.5	39.0
Mouse	2.8	0.0	0.5	0.0	3.2	4.8	9.9	0.0
All pests	1.8	10.5	0.4	5.7	26.2	5.5	13.4	12.2

Source: Balai Proteksi Tanaman Pangan dan Hortikultura, Propinsi Lampung. Laporan Musiman.

Figure 4. Area that suffered from locust and mouse attacks, per month, of rice and maize cultivations in Lampung Tengah, April 1996 - March 2000.



Source: Provincial Bureau of Statistics, Lampung.

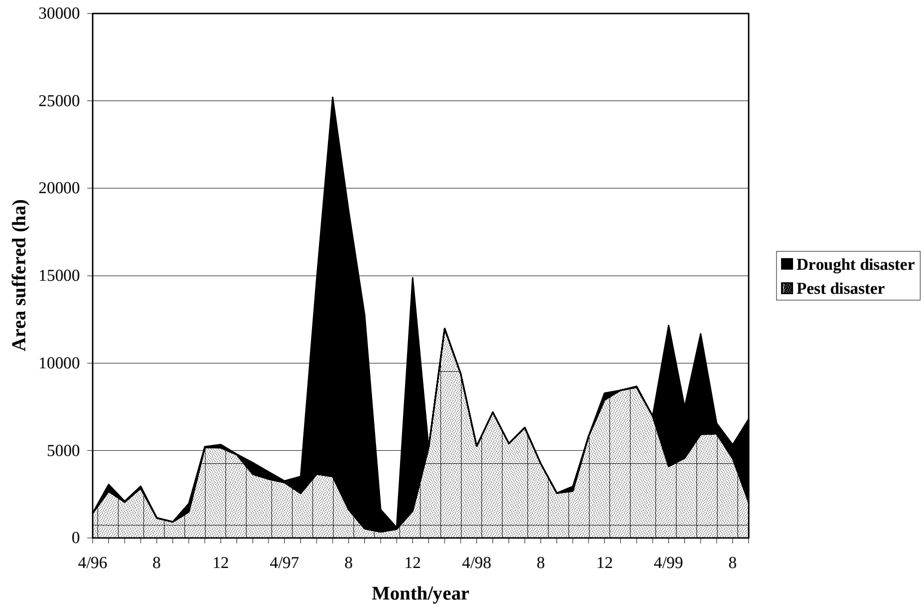
Structure of damage caused by El Nino 1997/98 on rice and maize cultivation

The two previous sections conclude that the El Nino of 1997/98 not only led to drought due to a rainfall decrease but also stimulated the occurrence of pest attacks. In other words, El Nino caused two negative impacts on farming activities: (a) drought as a direct impact of El Nino which caused a decrease in water availability, and (b) the increase of pest attacks after a long drought during the El Nino period, as an indirect impact. The question then, is: Which of the impacts caused greater losses to food production, whether through direct impacts (drought) or indirect impacts (pest attacks). The question should be clarified to enable policy makers to formulate effective and efficient mitigation efforts for future El Nino events.

Figure 5 shows the monthly evolution of total area that suffered from drought and pests of rice and maize crops in Lampung for April 1996 - September 1999. From this figure, it is clear that an increase in drought and pest cases occurred during El Nino (February 1997 - April 1998) and after the El Nino event. During the period of September 1996 - March 1997, before the El Nino, the maximum monthly area that suffered from drought and pests was only around 5,000 ha. This maximum coverage area augmented radically to be 25,000 ha in July/August 1997, during the El Nino event, due to drought. During the following months, the maximum coverage area was still high compared to the situation before the event, ranging from 8,000 ha to 15,000 ha per month due to increasing pest disasters which occurred until the wet season, 1998/99. These evolutions of drought and pest cases reveal that the impacts of the El Nino still exist, even after the event has ended.

Table 6 shows the structure of rice crop damage caused by El Nino, through direct (drought) and indirect (pest increase) impacts. It was assumed that indirect impact occurred only until the wet season of 1998/99, since in the dry season 1999 the pest attacks had drastically subsided.

Figure 5. Total area that suffered from drought and pest, of rice and maize cultivation in Lampung, April 1996 - September 1999



Source: Provincial Bureau of Statistics, Lampung.

Table 6. Structure of rice crop damage caused by the 1997/98 El Nino in Lampung

Variable	Season: Dry-1997	Wet-1997/98	Dry-1998	Wet-1998/99	All seasons
Area suffered (ha)	48,933	26,756	25,554	26623	127,866
1. Drought	37,967	7,251	10	61	45,289
2. Pest	10,966	19,505	25,544	26,562	82,577
- Locust	80	2,962	4,960	397	8,399
- Mouse	2,661	676	4,903	8,664	16,904
Share (%)					
1. Drought	77.6	27.1	0.0	0.2	35.4
2. Pest	22.4	72.9	100.0	99.8	64.6
- Locust	0.2	11.1	19.4	1.5	6.6
- Mouse	5.4	2.5	19.2	32.5	13.2
Area totally damaged (ha)	9,767	320	1,595	794	12,476
1. Drought	9,750	307	0	5	10,062
2. Pest	17	13	1,595	789	2,414
- Locust	0	2	458	274	734
- Mouse	7	0	789	496	1,292
Share (%)					
1. Drought	99.8	95.9	0.0	0.6	80.7
2. Pest	0.2	4.1	100.0	99.4	19.3
- Locust	0.0	0.6	28.7	34.5	5.9
- Mouse	0.1	0.0	49.5	62.5	10.4
Percentage area totally damaged compared with area suffered (%)					
1. Drought	25.7	4.2	0.0	8.2	24.0
2. Pest	0.2	0.1	6.2	3.0	7.3
- Locust	0.0	0.1	9.2	69.0	12.8
- Mouse	0.3	0.0	16.1	5.7	0.0

Source: Balai Proteksi Tanaman Pangan dan Hortikultura, Propinsi Lampung. Laporan Musiman.

The total rice area that suffered from drought and pests in the dry season of 1997 until the wet season of 1998/99 was about 128,000 ha and around 12,500 ha or 9.8 per cent of the total area that suffered became ‘puso’ area (or area completely damaged). Meanwhile, from the whole ‘puso’ area, about 81 per cent (10,062 ha) resulted from drought. This reveals that drought or direct impacts of El Nino were the major cause of production decreases in rice. However, the area that suffered from pests during those four periods of cultivation was larger than the area that suffered from drought, 64.6 per cent for pest and 35.4 per cent for drought cases, of the total area that suffered. The principle causes of difficulty in anticipating drought, over pest attacks, are technical and farmers capital constraints.

Table 7. Structure of maize crop damage caused by the El Nino 1997/98 in Lampung

Variable	Season				All seasons
	Dry-1997	Wet-1997/98	Dry-1998	Wet-1998/99	
Area suffered (ha)	28,183	13,207	10,380	14,490	66,260
1. Drought	25,209	3,856	0	637	29,702
2. Pest	2,974	9,351	10,380	13,853	36,558
- Locust	29	2,568	8,270	654	11,521
- Mouse	424	13	473	2,792	3,702
Share (%)					
1. Drought	89.4	29.2	0.0	4.4	44.8
2. Pest	10.6	70.8	100.0	95.6	55.2
- Locust	0.1	19.4	79.7	4.5	17.4
- Mouse	1.5	0.1	4.6	19.3	5.6
Area totally damaged (ha)	12,662	1,034	2,719	1,038	17,453
1. Drought	12,650	502	0	270	13,422
2. Pest	12	532	2,719	768	4,031
- Locust	0	532	2,658	305	3,495
- Mouse	2	0	15	134	151
Share (%)					
1. Drought	99.9	48.5	0.0	26.0	76.9
2. Pest	0.1	51.5	100.0	74.0	23.1
- Locust	0.0	51.5	97.8	29.4	20.0
- Mouse	0.0	0.0	0.6	12.9	0.9
Percentage area totally damaged compared with area suffered (%)					
1. Drought	50.2	13.0	0.0	42.4	30.0
2. Pest	0.4	5.7	26.2	5.5	26.0
- Locust	0.0	20.7	32.1	46.6	1.1
- Mouse	0.5	0.0	3.2	4.8	0.0

Source: Balai Proteksi Tanaman Pangan dan Hortikultura, Propinsi Lampung. Laporan Musiman.

Drought was also the major cause of production decline of maize farming during the El Nino event, even though the maize area that suffered from pests was higher than the area that suffered from drought (Table 7). In total, drought cases caused around 77 per cent of the total ‘puso’ area, which covered 17.453 ha in the dry season of 1997 until the wet season of 1998/99. Harvest failure resulting from drought, was particularly severe during the dry season of 1997 and the wet season of 1997/98 (during the El Nino event), while for pest cases it was particularly severe during the dry season of 1998 and the wet season of 1998/99 (after the El Nino event). As indicated in Table 6, the pattern of harvest failure by period of cultivation resulting from drought and pests was similar for rice. A large reduction in rainfall during the 1997 dry season (59 per cent) and 1997/98 wet season (28 per cent) was the major cause of high harvest failure due to drought during the two seasons of cultivation in 1997-1998.

In the case of maize, the increase in the locust population stimulated by El Nino was the major cause of harvest failure resulting from pests, it contributed around 87 per cent of the pest ‘puso’ area or 20 per cent of the total area completely damaged. The most significant locust attacks were observed during the wet season of 1997/98 and the dry season of 1998. The situation was different for rice; mouse were the significant pest after El Nino, they contributed about 53 per cent of the pest ‘puso’ area or 10 per cent of the total area completely damaged. Their occurrence was observed particularly in the dry season of 1998 and the wet season of 1998/99 (Table 6). The different patterns of pest disasters between rice and maize, for period of occurrence and degree of impact on area damaged, was due to three factors: (1) The increase in the locust population was earlier than in the mouse population. The drastic increase in locust numbers started in January 1998 or during the wet season of 1997/98, while for mouse it was in June 1998, during the dry season. (2) The increasing locust population started in dryland areas where most of the maize is grown, then moved to wetland areas. While the mouse population increase started on sawah land or irrigated land where most of the rice is grown, then moved to dryland areas. In other words, there was a spatial movement of the mouse population from wetland areas to dryland areas, while for locusts, it moved from dryland areas to wetland areas. (3) A combination of the two previous factors led to increasing maize crop damage due to the locust plague starting in the wet season of 1997/98. In the case of rice, increasing crop damage caused by mouse started in the dry season of 1998.

Impact analysis at farm and household levels

In upland areas, where irrigated land is relatively limited, such as at the research sites, rainfall becomes the major water source for food crop farming activities. Accordingly, El Nino, which leads to a rainfall decrease and temperature increase, will have a significant impact on agricultural production in such regions. In general, the impact was not only determined by the magnitude of the unfavorable climate induced, but also by mitigation efforts applied by the farmers. Risk management strategies, based on time frame, could be grouped into three categories (Malton, 1991; Downing *et al*., 1999): (1) Ex ante strategy, e.g. grain stocks for risk management at a household level; (2) Interactive strategy, e.g. change crop by replanting for risk management at a farm level; and (3) Ex post strategy, e.g. local non-farm work for risk management at a household level.

The following description reveals how seriously the El Nino of 1997/98 negatively impacted farmers and mitigation efforts applied by the farmers. The analysis focused on two levels or scopes of risk management, i.e. farm level and household level. Analysis at the farm level covered aspects of cultural practices, crop perturbation induced by unfavorable weather, and quantification of impacts on production losses. The analysis at household level was focused on household consumption, staple foods in particular.

Land holding and cultivation period shift during the 1997/98 El Nino

Agricultural land for plantation purposes in general, could be specified as wetland or irrigated land, and dryland or non irrigated land. Based on the pattern of its utilization, dryland could be further classified as dryland allocated for food crops (usually called *tegalan*), dryland allocated for perennial crops (called *kebun*) and home yard. In terms of water source and investment budget, irrigated land could also be grouped into three categories, i.e. technical irrigated land, semi-technical irrigated land and simple irrigated land (Bottema, 1995).

Technical and semi-technical irrigated land are groups of irrigated land with the water supply coming from water dams built by the government on big rivers, while the water supply for simple irrigated land generally comes from small rivers and most of its required investment budget comes from the village community. Simple irrigated land generally has less water availability and water continuity and consequently, lower crop intensity than technical or semi-technical irrigated land.

Table 8. Number of farm households and average land holdings per research site

Village	Number of farmers	Land holding (ha/household)			Percentage (%)	
		Wetland	Dryland	Total	Wetland	Dryland
Binjai Agung	18	0.25	1.25	1.50	15.8	84.2
Kedatuan	5	0.61	1.55	2.16	29.3	70.7
Tanjung Pandan	9	0.62	0.48	1.10	57.0	43.0
Trimulyo	8	0.41	1.22	1.63	29.3	70.7
All villages	40	0.41	1.11	1.52	29.4	70.6

Source: Survey data.

Most farmers in the research area owned dryland, which contributes on average 70.6 per cent of the total land holdings (Table 8). Only farmers in the village of Tanjung Pandan owned more irrigated land than dryland with a composition of 57 per cent for irrigated land and 43 per cent for dryland. All irrigated land owned by the farmers is simple irrigated. Water availability for such irrigated land and even more so for dryland, is fully dependant on rainfall, although water continuity on simple irrigated land is generally better than on dryland.

In dryland areas, the planting date for the wet season period applied by the farmers is highly dependant on the occurrence of the first rainfall of the period. Based on their experience, most farmers revealed that the dry season in the research area usually occurs during April-September (Table 9). In other words, the wet season usually covers 6 or 7 months and the dry season covers 5 or 6 months yearly. Although, during the El Nino event of 1997/98 the dry season occurred for longer (7 or 8 months), whereas the wet season was shorter (4 or 5 months).

Table 9. Frequency of farmers by pattern of period of wet season/dry season in the research area

Pattern	Wet season (month)		Dry season (month)		Frequency of farmers		Total month included (month)	
	Beginning	End	Beginning	End	Total farmer	Percentage (%)	Wet season	Dry season
Normal climate								
1	October	March	April	September	14	35.0	6	6
2	October	April	May	September	16	40.0	7	5
3	November	March	April	October	2	5.0	5	7
4	November	April	May	October	8	20.0	6	6
1997/98								
5	Nov-97	Mar-98	Apr-97	Oct-97	7	17.5	5	7
6	Dec-97	Mar-98	Apr-97	Nov-97	11	27.5	4	8
7	Dec-97	Apr-98	May-97	Nov-97	8	20.0	5	7
8	Jan-98	Apr-98	May-97	Dec-97	14	35.0	4	8

Source: Survey data.

Table 10. Frequency of farmers by planting date of rice, maize and cassava in the wet season

Month (week)	Normal wet season			Wet season 1997/98		
	Rice	Maize	Cassava	Rice	Maize	Cassava
Number of farmers						
September (week 3-4'th)	0	6	3	0	0	0
October (week 1-4'th)	4	9	5	1	1	1
November (week 1-4'th)	13	7	4	1	7	3
December (week 1-4'th)	5	0	0	4	9	8
January (week 1-4'th)	0	0	0	14	5	0
February (week 1-4'th)	0	0	0	2	0	0
Total	22	22	12	22	22	12
Percentage of farmers (%)						
September (week 3-4'th)	0.0	27.3	25.0	0.0	0.0	0.0
October (week 1-4'th)	18.2	40.9	41.7	4.5	4.5	8.3
November (week 1-4'th)	59.1	31.8	33.3	4.5	31.8	25.0
December (week 1-4'th)	22.7	0.0	0.0	18.2	40.9	66.7
January (week 1-4'th)	0.0	0.0	0.0	63.6	22.7	0.0
February (week 1-4'th)	0.0	0.0	0.0	9.1	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Survey data.

Other than inducing a longer dry season, El Nino 1997/98 also caused a shift in the wet season and dry season. Under normal climate conditions, the wet season usually starts in October/November but due to El Nino 1997/98 the season started in December/January. In other words, the wet season was delayed by two months.

In the research area rice, maize and cassava are the main food crops cultivated by farmers. Rice is usually grown on wetland, particularly during the wet season, whereas maize and cassava are usually cultivated on dryland under a mixed cropping system. Due to the smaller water requirement or higher tolerance to water restriction, maize and cassava are usually planted earlier than rice. Under normal climate conditions, those crops are normally planted in October/November, but during El Nino, farmers could not start planting until November/December because of the delay of the rainy season. The delay of the planting date also occurred for rice, from November/December under normal climate conditions to December/January during El Nino (Table 10).

Drought disaster, coping strategies and production loss

Due to water insufficiency induced by a decrease in rainfall, drought disaster is the most frequently reported impact of El Nino. To understand the impact of El Nino on the incidence of drought, qualitative information was collected from farmer respondents. Two main groups of the collected information are magnitude of drought in 1997/98 compared to normal conditions, and farmers' efforts to mitigate the drought problems.

Farmers of the research area generally own more than one plot of agricultural land, wet or dry. In total, of the respondents, there were 57 plots of dryland and 41 plots of wet owned. Of the total plots, around 95 per cent suffered from serious drought during the dry season, 1997 (Table 11). However, in the wet season of 1997/98 the area that suffered from serious drought was relatively low, less than 15 per cent, both for number of plots and area. This reveals that the increase of drought cases induced by El Nino actually occurred only during the dry season, which in 1997/98 occurred for 7 or 8 months, from April/May 1997 until November/December 1997.

Table 11. Area that suffered from drought by season in 1997/98 in the research area

		Dry season 1997				Wet season 1997/98			
		Total field suffered		Total area suffered		Total field suffered		Total area suffered	
Land type	Degree of attack	Field	Percentage (%)	Area (ha)	Percentage (%)	Field	Percentage (%)	Area (ha)	Percentage (%)
Dryland	High	55	96	43.3	98	3	5	2.0	5
Dryland	Medium	2	4	0.9	2	8	14	3.5	8
Dryland	Low	0	0	0.0	0	17	30	13.1	30
Dryland	None	0	0	0.0	0	29	51	25.6	58
Wetland	High	39	95	15.8	95	3	7	1.8	11
Wetland	Medium	2	5	0.8	5	5	12	2.0	12
Wetland	Low	0	0	0.0	0	9	22	3.6	22
Wetland	None	0	0	0.0	0	24	59	9.3	56

Note: High/Medium/Low degree compared with usual case.
Source: Survey data.

Drought during the dry season of 1997 not only happened on dryland, but also on wet or irrigated land. The occurrence of drought on irrigated land was caused by the fact that the water source for simple irrigated land was only from small rivers, which during El Nino ran dry.

Replacing crops with ones resistant to water stress was a strategy applied by farmers to lower the production risk due to water restriction. This strategy is usually applied by farmers when anticipating predictable water stress situations, such as during the dry season. In the dry season, when water availability is lower, farmers usually cultivate a relatively resistant-to-water-stress crop or variety. However, when the degree of water stress was unpredictable, such as in an El Nino case, the strategy could not be implemented.

The majority of the farmers did not realize, prior to the 1997 dry season, that it would be worse than usual. They only knew that there was a delay of the wet season, so the planting date for the dry season should be postponed. The condition made farmers not shift the cropping pattern to the high-tolerant-to-water-stress crop during this El Nino episode; instead they applied the usual cropping pattern.

Table 12. Frequency of farmers by mitigation method applied against drought disaster during El Nino 1997/98

	Land holding (ha)				
Method	0.50-1.00	1.25-1.50	1.75-2.00	2.25-3.50	All size
Total farmers	15	10	9	6	40
Number of farmers					
Replace cropping pattern with drought tolerant crop	0	0	0	0	0
Delay planting date	12	6	4	4	26
Replanting	1	0	0	1	2
Reduce crop intensity	1	1	0	1	3
Hire water pump	2	0	1	0	3
Buy water	0	0	0	0	0
Early harvesting	8	3	4	2	17
Percentage of farmers (%)					
Replace cropping pattern with drought tolerant crop	0	0	0	0	0
Delay planting date	80	60	44	67	65
Replanting	7	0	0	17	5
Reduce crop intensity	7	10	0	17	8
Hire water pump	13	0	11	0	8
Buy water	0	0	0	0	0
Early harvesting	53	30	44	33	43

Source: Survey data.

To reduce production risk due to water stress, delaying the planting date was the most preferred way with 65 per cent of the farmers applying this (Table 12). The second chosen way was earlier harvesting, or to put it another way, the harvest was conducted prior to the crops optimum harvest age. This was mainly carried out by farmers whose plantation was not fully ripe, usually maize. Earlier harvesting may also be implemented for partially damaged rice with the help of a rented water pump. This could only be carried out by farmers whose land is located near to a swamp, where water was still available in spite of the dry season.

Even though various mitigation efforts of water restriction during the dry season of 1997 were implemented, those efforts were not able to reduce production loss significantly. Table 13 shows food crop yields in the dry season of 1997 compared to normal climate conditions. From the table, it is clear that yield loss in the dry season was relatively high for maize, 55 per cent for dryland and 41 per cent for wetland. Yield loss for wetland rice was also high, around 34 per cent, whereas cassava, which is more resistant to water restriction had the lowest loss at around 19 per cent.

Table 13. Crop cultivated and production loss due to drought in the dry season of 1997

Land type	Pattern	Crop		Coverage area		Number of farmer		Yield (kg/ha)		Yield loss (%)
		Normal	1997	(ha)	(%)	Total	(%)	Normal	1997	
Dryland	1	Maize	Maize	1.5	3	3	8	2,470	1,105	55
	2	Cassava	Cassava	35.5	80	32	82	11,800	9,548	19
	3	Fallow	Fallow	7.2	16	4	10	-	-	-
Wetland	1	Maize	Maize	1.5	9	2	6	3,690	2,180	41
	2	Maize	-	2.1	13	5	16	2,283	-	100
	3	Rice	Rice	2.8	17	3	10	3,733	2,467	34
	4	Rice	-	6.9	42	13	42	3,996	-	100
	5	Fallow	Fallow	3.2	19	8	26	-	-	-

Source: Survey data.

Pest disaster, coping strategies and production loss

Besides drought, El Nino also stimulates an increase in pest perturbation. It started to increase in February/March 1998 or approaching the end of El Nino 1997/98. From a crop schedule perspective, February/March is the beginning of the wet season cropping period. Accordingly, the increase in pest attacks mainly happened during the wet season of 1998.

Table 14 shows the extent of pest attacks during the El Nino episode. There were 3 types of major pest in the research area, locust, mouse and snail, yet the most serious perturbation was caused by locust. Rice and maize were the major crops attacked by locust, while cassava experienced no significant perturbation increase. The increase of pest perturbations mainly happened during the wet season 1998 (December 1997 - March/April 1998), according to more than 75 per cent of the farmers.

The increase in locust attacks mainly occurred when the maize and rice reached their generative stage, 1-2 months after being planted. Total plot that suffered from locust attacks was 67 per cent and 76 per cent out of total dryland and wetland plots respectively (Table 15). This revealed that locust attacks during El Nino were well spread over all four analyzed villages. The increase in locust attacks mainly happened during wet season of 1998, whereas in the dry season of 1997, only about 5 per cent of wetland plots had the pest perturbation increase. However, locust perturbation increases did not occur on dryland plots during the dry season of 1997.

Table 14. Frequency of farmers by crop and pest disaster during 1997/98 in the research area

Crop	Variable	Number of farmers			Percentage (%)		
		Locust	Mouse	Snail	Locust	Mouse	Snail
Rice	Total farmer	31	31	31	100.0	100.0	100.0
	Occurrence						
	-Yes	29	7	3	93.5	22.6	9.7
	-No	2	24	28	6.5	77.4	90.3
	Date of occurrence						
	-Dry season of 1997	0	3	0	0.0	9.7	0.0
	-Wet season of 1997/98	29	4	3	93.5	12.9	9.7
	Attack period						
	-Vegetative stage	3	1	3	9.7	3.2	9.7
	-Flowering stage	3	1	0	9.7	3.2	0.0
	-Generative stage	26	5	0	83.9	16.1	0.0
Maize	Total farmer	40	40	40	100.0	100.0	100.0
	Occurrence						
	-Yes	31	0	0	77.5	0.0	0.0
	-No	9	40	40	22.5	100.0	100.0
	Date of occurrence						
	-Dry season of 1997						
	-Wet season of 1997/98	31	0	0	77.5	0.0	0.0
	Attack period						
	-Vegetative stage	3	0	0	7.5	0.0	0.0
	-Flowering stage	2	0	0	5.0	0.0	0.0
	-Generative stage	26	0	0	65.0	0.0	0.0
Cassava	Total farmer	34	34	34	100.0	100.0	100.0
	Occurrence						
	-Yes	3	0	0	8.8	0.0	0.0
	-No	28	34	34	82.4	100.0	100.0
	Date of occurrence						
	-Dry season of 1997	0	0	0	0.0	0.0	0.0
	-Wet season of 1997/98	3	0	0	8.8	0.0	0.0
	Attack period						
	-Vegetative stage	2	0	0	5.9	0.0	0.0
	-Flowering stage	0	0	0	0.0	0.0	0.0
	-Generative stage	1	0	0	2.9	0.0	0.0

Source: Survey data.

To cope with the locust problem, early harvesting was the most common counter-measure used by farmers (65 per cent of respondents). This was mainly carried out by farmers with a high intensity of locusts, when they predicted that cultivation would not be able to give the expected production. By implementing this strategy, farmers lost their grain production of rice and maize, yet they still could utilize the leaves as livestock feed. Actually, during the wet season of 1998, the livestock feed problem tended to increase resulting from harvest failure in the dry season of 1998 induced by a prolonged drought.

About 43 per cent of farmers tried to cope with locust attacks by the application of pesticides. This was mainly carried out by farmers with a low pest attack intensity or the cultivated crop had reached its flowering or generative stage. In general, this method was used by farmers who had cultivated earlier, around November/December 1997. However, due to the very high population of locust and its continuous increase, the strategy was not able to reduce production loss significantly.

Table 15. Area that suffered from pests by season of 1997/98 at the research sites

Land type	Degree of attack	Dry season of 1997: Total field suffered: Field	Percentage (%)	Total area suffered: Area (ha)	Percentage (%)	Wet season of 1997/98: Total field suffered: Field	Percentage (%)	Total area suffered: Area (ha)	Percentage (%)
Dryland	High	0	0	0.0	0	38	67	30.4	69
Dryland	Medium	0	0	0.0	0	8	14	4.8	11
Dryland	Low	9	16	7.7	17	6	11	4.3	10
Dryland	None	48	84	36.5	83	5	9	4.8	11
Wetland	High	2	5	1.3	8	31	76	13.4	81
Wetland	Medium	2	5	0.8	5	5	12	1.5	9
Wetland	Low	3	7	1.8	11	0	0	0.0	0
Wetland	None	34	83	12.8	77	5	12	1.7	10

Note: High/Medium/Low degree compared with usual case.
Source: Survey data.

Table 16. Frequency of farmers by mitigation method applied against pests disaster during El Nino 1997/98

Method	Land holding (ha): 0.50-1.00	1.25-1.50	1.75-2.00	2.25-3.50	All size
Total farmer	15	10	9	6	40
Number of farmers					
Increase pesticide utilization	5	3	7	2	17
Replace seed with pest tolerant variety	0	0	0	0	0
Early harvesting	10	6	4	6	26
Percentage of farmers (%)					
Increase pesticide utilization	33	30	78	33	43
Replace seed with pest tolerant variety	0	0	0	0	0
Early harvesting	67	60	44	100	65

Source: Survey data.

Table 17 shows the yields of rice and maize produced in the wet season of 1998 under normal climate conditions. From this Table, it is clear that the yield loss of rice was higher than that of maize. Under normal climate conditions, wetland rice can produce 5.0 - 6.6 tons of rice per hectare, but in the wet season of 1998 it produced only 2.3 - 3.7 tons per hectare, a decrease of 44 - 58 per cent. Whereas for maize, the yield decrease was around 35 - 36 per cent from about 3.5 tons to 2.2 - 2.3 tons per hectare.

Table 17. Crop cultivated and yield loss due to pests in the wet season, 1998

Land type	Pattern	Crop: Normal	Crop: 1997	Coverage area (ha)	Coverage area (%)	Number of farmer: Total	Number of farmer: (%)	Yield (kg/ha): Normal	Yield (kg/ha): 1997	Yield loss (%)
Dryland	1	Maize	Maize	1.5	3	3	8	3,527	2,278	35
	2	Maize	Maize	35.5	80	32	82	3,514	2,250	36
	3	Maize	Maize	7.2	16	4	10	3,523	2,297	35
Wetland	1	Rice	Rice	1.5	9	2	6	6,140	3,460	44
	2	Rice	Rice	2.1	13	5	16	5,000	2,317	54
	3	Rice	Rice	2.8	17	3	10	6,667	2,800	58
	4	Rice	Rice	6.9	42	13	42	5,281	2,946	44
	5	Rice	Rice	3.2	19	8	26	6,050	3,717	39

Source: Survey data.

Household food security and coping strategies for maintaining staple food consumption

Food security is one of the main focuses of agricultural development in Indonesia. El Nino can influence household food security through its impacts on food production failure. In upland areas, which are generally located in remote areas, rice production is relatively low due to the lack of suitable agricultural land and a low rate of technology adoption. Accordingly, food problems arise frequently in upland areas particularly when perturbation on local food production occurres due to weather variability. To anticipate the uncertainty of food production, two strategies usually carried out by farmers are: maintaining a sufficient stock of rice and combining rice consumption with other complementary staple foods.

In the research area, dried cassava has a function as a complementary staple food to rice, the main staple food. After being processed into traditional meal called “oyek”, dried cassava can be stored for a long period, about 8 to 10 months, without any significant quality degradation. The product also has a high energy content, about 2,200 cal/kg, while the energy content of rice is 3,600 cal/kg. In the case of rice scarcity, farmers usually consume the product in combination with rice.

The proportion of rice and “oyek” consumed is usually varied, it depends on the food cropping pattern applied by the farmer. During the wet season, when most the farmers cultivate rice, the consumption of “oyek” is usually low but it increases during the dry season due to the low production of rice. In a normal climate situation or normal production of food crops, rice consumption per household per week on average was 10 kg during the dry season and 11 kg during the wet season, while consumption of “oyek” is respectively 1.2 kg and 0.6 kg (Table 18). More than 75 per cent of consumed rice came from the farmers own production, while the level of self production of dried cassava was only around 10 per cent, since cultivation of cassava was generally market orientated, particularly for local tapioca factories.

Table 18. Staple food consumption per week per household

Staple Food	Normal climate		El Nino 1997/98		Change	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Consumption (kg)						
- Rice	10.0	11.0	7.5	8.0	-2.5	-3.0
- Dried cassava	1.2	0.6	5.0	5.1	3.8	4.5
Self production (%)						
- Rice	75.0	78.1	55.0	62.5	-20.0	-15.6
- Dried cassava	15.0	5.0	32.0	29.5	17.0	24.5
Calories intake (cal)						
- Rice	36,000	39,600	27,000	28,800	-9,000	-10,800
- Dried cassava	2,640	1,320	11,000	11,220	8,360	9,910
- Total	38,640	40,920	38,000	40,020	-640	-900

Source: Survey data.

Due to the El Nino of 1997/98, rice production decreased significantly. This situation led in turn, to a decrease in rice consumption, becoming 7.5 kg per household per week in the dry season of 1997 and 8.0 kg per household per week during the wet season of 1998. On the contrary, consumption of dried cassava steeply increased, around 4 kg per household per week, 4 times higher compared to the consumption level during normal conditions. The level of self produced rice also declined to 55 per cent in the dry season of 1997 and 67 per cent in the wet season of 1998, while self produced dried cassava rose by 30 per cent for both seasons since cassava production did not decrease significantly during El Nino episode.

Although the change in staple food consumption patterns occurred during the El Nino event, its impact on household calory intake was not significant. Compared to normal consumption, the decrease in calory intake was only 2 per cent for both the dry season of 1997 and the wet season of 1998. Assuming that rice and cassava consumption contributes 63 per cent of the total calory intake in rural areas (SUSENAS, 1999), the figure indicates that the El Nino of 1997/98 had no significant impact on food security at a household level.

As previously mentioned, the level of self produced rice consumption decreased during the El Nino event. This meant that more rice purchasing must be undertaken by farmers to maintain their consumption requirement, in other words, an additional food consumption budget was needed. In general, selling the farmers animals, particularly chicken and sheep, was the most common way carried out by farmers; 47.5 per cent out of the total respondent farmers applied this coping strategy (Table 19). Other methods are money borrowing from a neighbor, jewelry selling, off-farm working and others such as firewood selling.

Table 19. Frequency of farmers by strategy applied for maintaining food consumption during the El Nino, 1997/98

Strategy	Dry season		Wet season		All	
	Frequency	%	Frequency	%	Frequency	%
a. Animal selling	14	35.0	5	12.5	19	47.5
b. Jewelry selling	3	7.5	0	0.0	3	7.5
c. Electronic selling	0	0.0	0	0.0	0	0.0
d. Borrow from neighbour	5	12.5	1	2.5	6	15.0
e. Borrow from local institution	0	0.0	0	0.0	0	0.0
f. Off-farm working	2	5.0	0	0.0	2	5.0
g. Others	3	7.5	0	0.0	3	7.5

Source: Survey data.

Government coping mechanisms against El Nino

Institutional preparedness represents mitigating measures required to reduce the adverse impact of climate variability such as an El Nino event. In fact, several coping mechanisms have been established by the Indonesian government. Some of the coping mechanisms were updated after the big El Nino of 1997/98 which induced a food crisis nation wide. The following description is devoted to identifying major coping mechanisms undertaken by government institutions.

Climate forecasting and the establishment of a climate task force

El Nino 1997/98 was the biggest one of the century. No El Nino event in history has been given the international attention of the 1997/98 El Nino (Fox, 2000). This El Nino was well predicted in advance of its onset and considerable attention was given to its likely severity and potential impacts. Its course was monitored closely and information was widely available through international electronic data.

The information was, however, not available to farmers in Indonesia. This might have happened because of two factors: (1) There was no institutional mechanism that could rapidly distribute El Nino's information to the farmers, (2) After the general election which was held in May 1997, political issues in Indonesia became hotter. Since mid 1997, Indonesia has been suffering from an economic crisis due to a drop in the rupiah's value. Both conditions ensured that information conveyed by the mass media was more focused on political and economical issues, primarily sectors other than agriculture, since those sectors felt the largest impact of the crisis.

In Indonesia, the main agency responsible for the monitoring and forecasting of climate variability is the Bureau of Meteorology and Geophysics (BMG). The BMG issues rainfall forecasts which are published in monthly climate reports. All regions of Indonesia were classified into 102 rainfall zones with differences in seasonal period, magnitude of rainfall, temperature and rainfall forecasting published by season. During the El Nino of 1997/98 the information was however, not available to farmers who had to determine their own particular planting strategies in facing a shortage of good rain.

The mechanism of dissemination of climate information, however, has been improved in recent years. In anticipating the issue of El Nino 2002, the climate task force was established in each province. The task force involves BMG, local agricultural agencies and other related government institutions. The task force was also established at a national level with three main activities: (1) disseminating, as rapidly as possible, rainfall and El Nino forecasts to farmers, (2) mapping vulnerable regions to drought and (3) preparing anticipation programs to drought and other agronomic perturbation induced by El Nino. An earlier planting date in the wet season represents the main strategy suggested for farmers to avoid food production loss in the dry season due to a prolonged dry season during El Nino. In the case of Lampung, subsidized rice seed and shallow tube well construction were also prepared by the local government.

Social Safety Net (SSN) program

The El Nino of 1997/98 caused a decrease in production for most food commodities nation wide. Reduced rice production, coinciding with the economic crisis, led to the food crisis. The rice price rose 300 per cent during the crisis. The crisis affected food security in urban areas through unemployment and the consequent decline in household incomes and access to food. In rural areas, the crisis also interfered with food security through the increase of migration to rural areas, which in turn led to increased competition for jobs and depressed wages. Moreover, as most migrants were landless and had little savings or assets, their susceptibility to food shortages became more pronounced.

The Social Safety Net (SSN) was initiated to overcome the effects of the economic crisis and food crisis induced by El Nino. Generally, SSN policy was intended to improve and speed up the ability to overcome the effects of the crisis, especially for people in villages, rural and small towns who were the worst hit. One of the priorities of the SSN program was improving food security through securing the supply of basic staples at affordable prices (Sumodiningrat, 1999). Amongst other means, this was achieved through subsidizing the rice price.

The program involved BULOG (National Food Agency) in distributing subsidized rice to the needy household markets, through a mechanism called ‘special market operation’. Under this program BULOG provided 10 kg of rice per household per month at Rp 1,000 per kg to registered, needy households. For this purpose, needy households had to be registered through their village organization or other local agencies. The government made an initial estimation of the number of the most needy households in every province in Indonesia and set its target at 7.35 million households, but this estimation was raised to 16.8 million households as the program expanded (Fox, 2000).

Establishment of famine rice barns

As a result of El Nino together with the economic crisis, Indonesia suffered from a severe food crisis in 1997/98, which was indicated by the increase of imported rice from 1.5 million tons in 1997 to 5.8 million tons in 1998. The crisis caused staple food problems, particularly in upland areas which are generally remote areas. Generally in such areas, farmers can grow only one rice crop in the wet season with a productivity per hectare about 2-3 tons of rice. This production pattern results in a discontinuity of the rice supply, which often is the main problem for food security in upland areas, especially by the end of the dry season, which occurs during May - September.

Establishment of a famine rice barn is a strategy carried out by the government to anticipate food insufficiency during a famine season. This policy started to be realized in 1999 after the occurrence of the food crisis in 1997/98. The priority of the strategy is in poor areas (IDT villages) which often have an insufficient rice supply during a famine season. In its implementation, management of the rice barn is carried out by Farmer Groups with a membership of 30 - 40 farmers per group.

In the research area, famine rice barns had actually been built by local farmers since 1989. The famine rice barn tradition was initiated by transmigrants coming from Java who had settled since the 1970's. Therefore, the governments' role in the development of rice barns was just to upgrade the existing ones, which is conducted by giving supporting funds of 4 - 5 million rupiah for each barn. The management of the rice barn was entirely delegated to the Farmer Group.

In accordance with an agreement between members of the Farmer Groups, every farmer stores about 1 quintal of rice per hectare after harvesting in the wet season. With member numbers of 30 - 40 farmers per group, every year around 3-12 tons of rice will be stored for each Farmer Group, depending on member numbers and the sawah areas they own. The rice can be utilized for various purposes, such as:

(1) Loaned to farmers who need rice for household consumption or farming capital. In this case, member and non-member farmers have the same opportunity to borrow rice from the barn. In other words, farmers with no contribution to the total stored rice are also able to borrow rice for their household needs. The borrowed rice then should be reimbursed after the rice harvest of the following year.

(2) Maintenance of the irrigation network. Rice allocation for repairing the irrigation network is usually carried out by the end of the dry season, approaching the wet season planting time. In this period, around October - November, the stored rice is distributed to all members of the Farmer Group. Prior to that, some of the rice is allocated for repairing the irrigation network. The amount of rice sold for this purpose is adjusted to the required fund.

(3) In the case of a lack of rice caused by harvest failure, the stored rice is loaned to members of the Farmer Group and farmers around. In the case of El Nino 1997/98 which caused rice harvest failure in both the wet and dry season, every household received loaned rice, around 80 kg on average, or approximately 10-20 per cent of the total required rice per household per year.

In the research villages there were 11 units of famine rice barns with a storage capacity of 5-15 tons of rice. Most of the barns were built by the village community and only one barn was built using government aid, managed by the Agriculture Office of Lampung Province. Six barns were built in 1990-1999 and four barns were built between 1999-2002 by the local community. An increasing rate of rice barn construction during the last period showed that the existence of famine rice barns was required by the local community.

Water pump program

Water insufficiency resulting from a rainfall decrease is a common impact induced by El Nino. This can cause a significant impact on food crop production, particularly for plantations requiring relatively high amounts of water, such as rice. To eliminate the probability of production failure resulting from water insufficiency, additional water sources are required to support the existing ones for irrigation. Construction of shallow tube wells is one way adopted by the local government of Lampung to overcome the water problem, which generally occurs during the dry season.

In general, agricultural land for food crops can be grouped into, irrigated land which is generally located on lowland areas, and non-irrigated land located on upland areas. Development of water pumps in the province of Lampung was emphasized on irrigated land based on two considerations, which are: (1) investment for constructing pump irrigation on non-irrigated land, which is generally located in upland areas, is relatively high, and the impact of the investment on the increase of food production is relatively low considering that crop intensity and rice productivity on dryland is relatively low. In other words, the efficiency of the water pump investment for food crop security on non-irrigated land areas is lower compared to irrigated land. (2) Technically, the development of water pumps is easier on irrigated land than on non-irrigated land despite the lower investment. The impact of the investment on the increase of rice production is also relatively high, particularly for rice plantations during the dry season when there is water insufficiency.

During 1998-2000, the local government of Lampung distributed an aid fund for the construction of shallow tube wells and water pumps to farmers. The aid covered 69 units of shallow tube wells and 155 units of water pumps. During the period, 9 water catchments and 12 deep tube wells were also constructed, but in 2001 the policy was withdrawn since it was judged as non-efficient in overcoming water shortages for irrigation. Therefore, since 2001 the program became more focused on the construction of shallow tube wells with irrigated land as the target. In 2001, as many as 437 shallow tube wells were constructed supported by 102 water pumps.

The supportive fund for the water pump program was distributed through Farmer Groups. Each group received one water pump (5.5 HP) and 5 shallow tube wells constructed on different farmer's lands. Overall maintenance, operational costs and the arrangement of pump utilization among the farmers was performed by the Farmer Groups themselves. Using this formula, it was expected that the construction of shallow tube wells would be able to irrigate around 4-5 ha of rice in the dry season. However, in reality, the pumps are not always utilized just for rice farming, but also for secondary crops such as maize and soybean or vegetable crops such as chili. Replacement of the target crop may happen because of two factors, which are:

(1) Volume of water supplied through the pump was not sufficient to irrigate rice, which has a relatively high water demand compared to other crops. This condition could result from the small size of the pump or limited water availability.
(2) Farmers who utilized the pump had to pay a rental cost to the Farmer Group which in turn, would be allocated as a maintenance cost. If the rental cost was assumed too expensive, then its utilization for rice was estimated as unprofitable. In this case, farmers will generally carry higher value crops, such as vegetable crops.

Conclusion and policy implications

The study on secondary data of food crop variability and rural households, in relation to climate variability in Lampung drew the following conclusions and policy implications:

(1) The El Nino of 1997/98 led to an average rainfall decrease of 59 per cent in the dry season of 1997 and 28 per cent in the wet season of 1998. The rate of rainfall decrease tended to be higher in upland areas where most CGPRT crops are grown.

(2) El Nino’s that occurred from 1975-2001 caused food crop area decreases, the opposite of La Nina. The highest area drop during an El Nino episode occurred for dryland rice (28 per cent) while cassava was the most resistant crop to drought. The impact was also low for wetland rice (2 per cent) due to irrigation network support. While maize, groundnut, sweet potato and soybean on average decreased between 6 per cent and 10 per cent.

(3) In the case of El Nino 1997/98, increasing drought and pest disasters were the main causes of food production failure. Drought was particularly intense in the dry season of 1997 and pest increases occurred in the wet season of 1998. The pest increase not only occurred during El Nino which covered the period of March 1997 – April 1998, but also in the two following cropping periods (dry season of 1998 and wet season of 1999). Locust was the main pests in the wet season of 1998 while mouse were in the three following seasons.

(4) Delaying the planting date was a common coping strategy applied by farmers to reduce possible production decreases of food crops during drought. Early harvesting was the second common strategy and other efforts applied by a limited number of farmers were: hiring water pumps, replanting and reducing crop intensity. However, all the coping strategies applied could not reduce production loss significantly. Production loss per hectare due to drought at the farm level was around 41-55 per cent for maize, 34 per cent for wetland rice and 19 per cent for cassava.

(5) A dramatic increase in the locust population was the main perturbation in the wet season of 1998. Early harvesting was the main effort applied by farmers to reduce possible production loss, as well as increasing the use of pesticides. Production loss due to locust was estimated at 35 per cent for maize and 44-58 per cent for wetland rice. The lower impact on maize compared to rice was caused by the fact that when the locusts came to the farmers, the field maize crop had reached a more suitable maturity stage than rice.

(6) Although the El Nino of 1997/98 caused a food production decrease, its impact on household calorie intake was not significant. The change of staple food consumption from rice to its combination with dried cassava was the main strategy applied to maintain sufficient staple food consumption. To provide an additional consumption budget for purchasing rice, animal selling was the main method used. Other ways applied by a limited number of farmers were borrowing money from neighbors, jewelry selling and off-farm working. Famine rice barns, established by local communities, also contributed to maintaining the fulfillment of the rice requirement for household consumption.

(7) Most coping strategies applied by farmers could be classified as an interactive strategy. In the case of climate variability resulting in a prolonged drought this strategy was not suitable for upland areas because when the drought came there would be no water available in the areas. In this case, drought forecasting and other related climate parameters provided by the government would be very helpful to farmers. By knowing

this information, farmers could carry out ex-ante coping strategies such as replacing usual crops or varieties with higher water tolerant ones.

(8) Early planting before the El Nino came in the wet season, was one of the governments efforts to reduce possible production loss due to a prolonged dry season. By applying this strategy it was expected that the production loss of dry season cultivation could be avoided. The strategy however, was not easy to implement because of difficulties in land preparation for hard soil, usually formed by the end of the dry season due to the high temperature as well as lack of rainfall. Accordingly, additional costs of land preparation should be provided to the farmers, indeed, a farmer's budget constraints are usually high during the dry season resulting from low agricultural production.

References

Bottema, J.W.T., 1995. Market Formation and Agriculture in Indonesia from Mid 19^{th} Century to 1990. Tesis (Dr). Katholieke Universiteit Nijmegen.

Downing, E., Olsthoorm, A.A. and Tol, R.S.J., 1999. Climate Change and Risk, London and New York: Routledge.

Fox, J.J., 2000. The impact of the 1997-1998 El Nino on Indonesia. *In* R.H. Grove and J.Chappell (eds). El Nino - History and Crisis. Studies from the Asia-Pacific Region, Cambridge, UK: White House Press.

Gomez, R., 1998. Climate-Related Risk in Agriculture. A Note prepared for the IPCC Expert Meeting on Risk Management Methods. Toronto, 29 April – 1 May 1998.

Irawan, B., 2002. Stabilization of Upland Agriculture Under El Nino-Induced Climatic Risk: Impact Assessment and Mitigation Measures in Indonesia. Working Paper No. 62, Bogor. Indonesia: CGPRT Centre.

Malton, P.J., 1991. Farmers Risk Management Strategies: the Case of the West African Semi-arid Tropics. *In* Holden, D; Hazeel, P and Pritzhard, A. (eds). Risk in Agriculture, Washington DC: World Bank.

Mukhopadyay, S.K., 1974. Source of Variation in Agricultural Production: A Cross Section - Time Series Study of India. Thesis (Dr). University of Minnesota.

Sumodiningrat, G., 1999. Economic stabilization and social safety net: achieveing public prosperity. International Seminar on Agricultural Sector During the Turbulence of Economic Crisis: Lessons and Future Directions, Bogor, Indonesia: Center for Agro-Socioeconomic Research.

Yoshino, M., Yoshino, K.U. and Suratman, W., 2000. Agricultural Production and Climate Change in Indonesia. Paper presented at the Symposium of Commission Climatology, IGU at Seoul, Korea.

Comments on the Indonesian Country Report

Nizwar Syafa'at[*]

I would like to express my sincere appreciation to the author for his presentation on "Impact of El Nino 1997/1998 and Mitigation Measures: Case of Lampung Indonesia". These research results are very useful for policy makers to formulate policies dealing with the negative impacts of the El Nino phenomenon.

Naturally, most agricultural products in the world are dependent on climate (natural environment). Drought, caused by the El Nino phenomenon, affects greatly agricultural production in the world. For a developing country like Indonesia, where most of the population depends on agriculture, drought induced by the El Nino phenomenon greatly reduces agricultural production capacity especially that of staple foods, therefore sharply reducing food supply and farmer's income. The El Nino incidence can be catastrophic, covering multiple countries and hence, causing a sharp decline in national or global agricultural supplies. International prices of agricultural products, food in particular, may increase significantly. The cumulative impact may cause severe food insecurity problems in some countries. The El Nino phenomenon is indeed, one of the most significant food security risk factors. The problem isn't just confined to individual or single countries, it is a regional or even global problem.

Dr Irawans' study, I think is beneficial to improve database information about the El Nino impact on staple food (rice and maize) production in Indonesia. To my knowledge, there has been no such study in Indonesia with such detailed analysis on the impact of El Nino. This data may be used as a first step toward building a comprehensive database on the El Nino phenomenon. I urge Dr Irawan to expand and update his database. Perhaps, the CGPRT Centre may also be interested and have the capacity to coordinate this effort.

To focus the impact analysis of El Nino on rice and maize production is the right choice because these crops are the most sensitive to El Nino induced drought. As we know, rice and maize require a lot of water, so drought induced by El Nino could cause water stress on these crops, and therefore sharply reduce crop production.

In Indonesia, rice is the major staple food. Total harvested area of rice is 11 million ha, widely spread throughout the country. Under normal conditions, rice production reaches 52 million tons and the domestic consumption level is more or less the same as production. The difference between production and consumption is very small, and therefore a decline in rice production will give rise to the need for rice imports. In 1997/1998, rice production was battered by El Nino and market disruption arising from the financial crisis. Production fell to some fifteen per cent below the domestic consumption requirement and in 1998, imports reached historical highs, estimated at about 5.8 million tons. This is indeed large, the total in the world market was only 12 million tons and therefore, Indonesia became the largest importer in the world.

The large volume of Indonesian imports pushed the rice price in the world market to historical highs. The world rice price increased sharply and Indonesia had to spend a lot of money (in US $) and worsen the already bad deficit balance of payment. This condition affected national economic stability. Indirectly, El Nino affects national economic stability. Therefore, a

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deep understanding of the impacts of El Nino in this research is very useful in formulating efforts to cope with it's wide and severe negative impacts.

The field data and information in the Dr Irawan research paper is rich, enough for us to understand the impacts of El Nino on agricultural production, especially staple food production.

However, I think his conclusion and recommendations can be further sharpened and expanded. In particular, what the government, farmers and their community should do to anticipate and to cope with the negative impacts of the El Nino phenomenon. The following are some of my suggestions on coping strategies in anticipating the El Nino phenomenon:

Capacity building on El Nino forecasting and early warning systems

El Nino is a global phenomenon, occurring in multiple countries simultaneously, and its accordance is unpredictable. Early prediction and warning systems are key for preparing the necessary coping mechanisms to minimize the hazardous impacts. For efficiency and effectiveness, countries vulnerable to the El Nino phenomenon should collaborate in establishing a network of climatic data and information as well as a joint effort on building a comprehensive forecasting model. Regarding the El Nino global phenomenon, we suggest that the government of Indonesia (GOI) should establish the El Nino Early Warning System. Collaboration between vulnerable Asian countries and the GOI is important to build the El Nino Early Warning System at a regional level.

Anticipated coping mechanisms

The government and farmers should collaborate to anticipate the negative impacts of El Nino, as early as possible:

Farmers

- Farmers adjust their cropping calendar according to the anticipated El Nino occurrence.
- Farmers plant drought resistant crops.
- Farmers can use intermittent irrigation technology to save irrigation water.
- Establishing water reservoirs (Embung).

Government

- Supplying sufficient seed as performer requirement. The government could collaborate with private seed producers such as P.T Sang Hyang Sri, to increase seed production by 10 percent above the normal consumption level if the El Nino incidence is predicted to be imminent.
- Strengthen the national and regional food stock through food imports.
- Encourage farmers to increase their food stock.
- Identify the regions which are most vulnerable to the El Nino phenomenon in Indonesia (mapping the vulnerable areas).
- Establishing an institution to deal with El Nino (The El Nino Crisis Center). The institution should be integrated at each vertical level of administration: national, provincial, district, sub district and village levels. This institution should act as a crisis centre to evaluate the climate condition and to prepare agricultural technology to anticipate negative impacts of El Nino and also to inform the farmers. The coordinator of this institution should be the head of the local government and the members from

related institutions. At a national level, the crisis centre may be coordinated by the Senior Minister of Welfare (Menteri Koordinator Bidang Kesejahteraan Rakyat), in the province by the governor, in the district by bupati (head of district), in the sub district by camat (head of sub. District) and in villages by the head of the village.

I shall conclude my comments by stating that the government should prepare an ANTICIPATED STRATEGY to cope with negative impacts of the El Nino phenomenon as well as EMERGENCY PLANT, because if El Nino has already occurred, it is too late to avoid the worst. The GOI should collaborate with other countries to exchange climate data and information, to build El Nino forecasting capacity and to strengthen the information and database system at a national as well as a regional level. This information is useful for setting up an integrated early warning system of El Nino occurrence.

Finally, to establish an El Nino forecasting and Early Warning System in Indonesia, rigorous human skill improvement training and long-term education, as well as institution building are needed.

El Nino Induced Climate Change and Malaysian Agriculture: Impact Assessment and Coping Mechanisms

Ariffin Tawang and Tengku Ariff Tengku Ahmad[*]

Introduction

For the past few decades, the agricultural sector in Malaysia has been fairly stable and predictable. This is partly due to the limited periodic variation in climates. However, for the past twenty years or so, there were more frequent and rampant abnormal weather phenomena, brought about predominantly by El Nino induced climate change or abnormal weather. These incidences significantly affected this stability and hence, resulted in some negative impacts to the agricultural sector specifically, and to the economy as a whole.

Basically, the El Nino episode resulted in prolonged dry season and severe drought, higher temperatures and deterioration in air quality and light penetration. Theoretically, these changes could bring serious implications to crop growth and yield, and consequently affect the economic contribution from the agricultural sector. Hence, a 'strong' and devastating El Nino episode, if remained unchecked and without proper mitigating measures, could trigger an environmental disaster and pose serious problems to agricultural and food production in this country.

This paper aims to describe and quantify the impact of El Nino induced climate variability on agricultural production and the rural economy, and the current coping mechanisms and risk management measures already established in order to minimize their impacts on the agricultural sector in Malaysia. This paper heavily depended on the outputs generated from the first phase of the study (Ariffin Tawang *et al*., 2002). Additionally, this paper also attempts to describe the impact of El Nino episodes at the regional or sub-national level (state) and farm levels.

For the purpose of the regional and farm level assessment, the Kedah-Perlis region was chosen. This region lies in the northwestern part of Peninsular Malaysia. The choice of this region as the area to assess the 'down - scaling' effect of El Nino from the national to the sub-national and farm levels was based on the following considerations:

a. *Drought prone area*

This is the only region in the country, which has a distinct and regular dry season, usually between the months of December and March. Hence, the incidence of drought during the dry season is quite prevalent. Under such a situation, it is argued that the impact of the El Nino induced climate change, especially the prolonged dry period associated with El Nino, could lead to much longer drought in this region, relative to other parts of the country. Theoretically, this should be the most badly affected region, due to El Nino, in the country.

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b. *Agricultural-based economies*

This is a highly agricultural-based region, where the agricultural sector contributes about one-third of the GDP and almost half of the employment. Hence, any 'forces' that would influence the performance of the agricultural sector would have a significant impact on the economy and employment in the region.

c. *Low income level*

The Kedah-Perlis region is among the poorest regions in the country, where per capita income is equivalent to about two-thirds of that of the national income level. Most of the low-income groups are within the agricultural sector in the rural areas. Hence, any climate variation, which affected the agricultural sector, could result in grave economic losses to the farmers.

d. *Food producing region*

This is the rice bowl of the country, where about forty per cent of the total domestic rice production comes from. The region is also the main producing area of sugarcane, mango and rubber. These four commodities occupy about 90 per cent of the total agricultural land in the region.

e. *Efficient water-use management*

There is a fairly high level of water-use efficiency in the region, particularly within the Muda Irrigation Scheme (MADA) and sugarcane plantations. This could provide a good example on how the efficient water use management could help in ensuring as little damage as possible from El Nino events.

El Nino and climate variability

Malaysia is comprised of the eleven states in Peninsular Malaysia, Sabah and Sarawak. It is situated in an equatorial region, hence the typical tropical climate. The general features of Malaysia's climate are that of high humidity and abundant rainfall ranging between 1,600 mm to 2,500 mm annually, and high and uniform temperatures with a mean daily temperature between 26^{o} C to 28^{o} C. By virtue of its equatorial climate too, there is absolutely no cold season due to the small seasonal variation in incoming solar radiation over the years. Variations in temperature are usually small and mainly due to the degree of cloudiness. The summary of the 'normal' Malaysian's weather is shown in Figure 1.

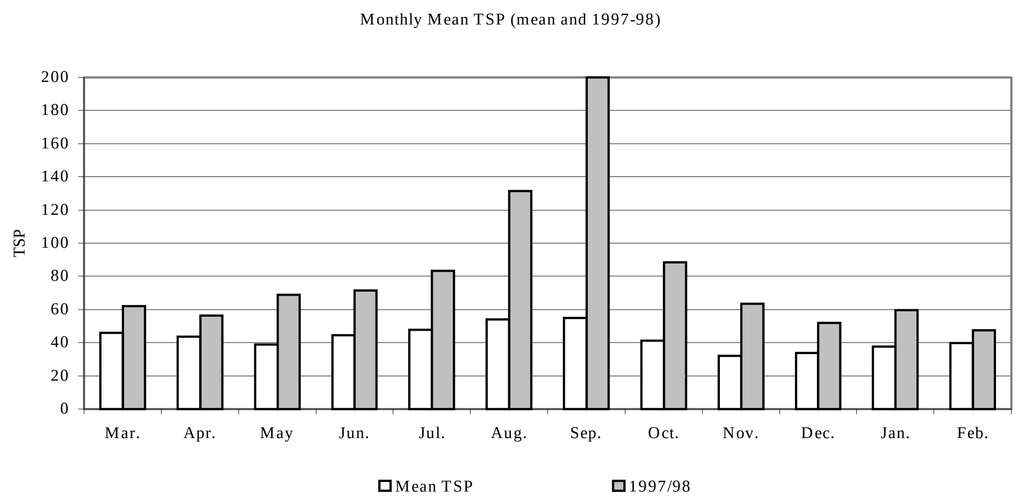
However, for the last twenty years, there was more frequent and rampant abnormal climate, particularly due to the El Nino induced weather variability. Since 1950, there were twelve major El Nino events recorded in the country. During the same period, seven La Nina events had also been recorded. The worst El Nino event affecting the country was the 1997/98 event, which began in March 1997 until June 1998. This episode resulted in a significant change in weather for the country as reflected in Figure 1. This was followed by the La-Nina of 1998/99. The previous major event was the El Nino of 1982/83.

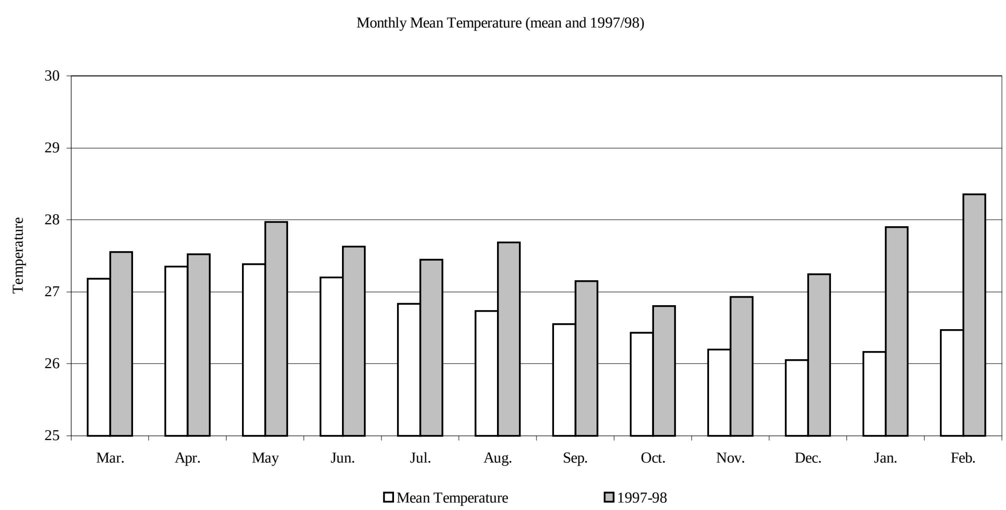
Generally, the immediate effect of all El Nino episodes was the delaying in the monsoon rains, which resulted in abnormal dry weather and an increase in daily temperatures. In the past few years, the prolonged drought encouraged forest fires, and the resultant pollution (in the form of haze or smoke) remained airborne due to little rain to 'wash' it away. Many of these fires were set up deliberately by plantation houses and timber companies to clear land, since this was considered as the cheapest and the most practical methods for land preparation. The practice of shifting cultivation by small farmers aggravated the problem further. The resultant pollutant produced far greater implication with respect to severe deterioration in air quality, which was more detrimental than that of drought alone.

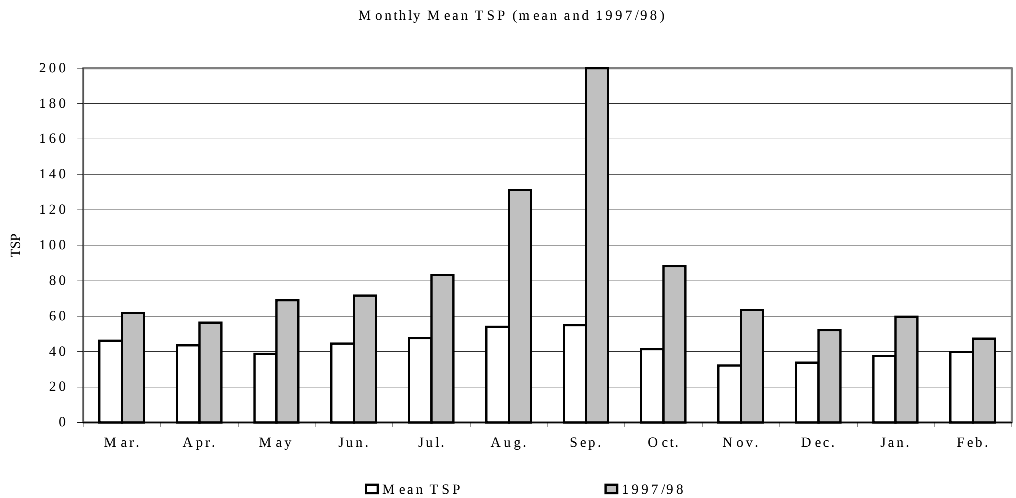
Impact on rainfall

The impacts of the previous El Nino incidences, in terms of less than normal rainfall, were observed particularly in Sabah and Sarawak, due to their close proximity to the Equator. In Peninsular Malaysia, the impact was noticeable only in the northwestern states (Lim Joo Tick, 1998), where seasonal droughts are fairly common. However, during the recent El Nino, the impact was felt throughout the country.

Figure 1: The Malaysian climate: mean and El Nino of 1997/98







Source: Malaysian Meteorological Service.

During the El Nino episode of 1997/98, the reduction in rainfall was fairly significant for all regions, ranging from about 100 mm in the northwest region (where the states of Kedah and Perlis are located) of Peninsular Malaysia to that of almost 1100 mm in Sarawak, an equivalent in rainfall reduction, of between 5 per cent to 26 per cent respectively. Similarly, the number of rainy days showed a significant reduction for all regions, ranging between 13 days in Central Interior to that of 51 days in Sabah, a reduction of between 8 per cent to 28 per cent respectively.

Apparently, it looks like the northwest region was the least affected in terms of total rainfall during the previous El Nino year, even though the level of rainfall for the region was among the lowest at 1,800 mm during the period March 1997 to February 1998. In fact, between the months of March to July 1997, the rainfall differential was 159 mm, and this was the period when water was required for the off-season paddy production in the region. Being one of the most important agricultural regions of the country, especially with respect to rice production, such an anomaly could be harmful to the rice industry.

Impact on mean daily temperature

The overall increase in the mean daily temperature between the 'normal' (based on the 50-years data) and El Nino years was between 0.5^o C to 1.7^o C for all regions. However, during the El Nino period of 1997/98, the mean daily temperature increased further in all regions, as compared to the 'normal' years. The variations in temperature for all regions ranged from 0.4^o C in the Central Interior region to 1.1^o C in the southern region. The significant increase in temperature could be due to the prolonged dry weather, coupled with the 'thick' haze.

Impact on air quality

The El Nino induced climate variability resulted in the prolonged dry weather throughout the country, as well as in neighboring countries. These induced widespread forest and peat swamps fires, which could not be controlled successfully especially in Sumatra and Kalimantan, Indonesia. With the prevailing winds, the smoke particles were transferred toward Malaysia, which resulted in heavy haze condition. The domestic pollutants from motor vehicles and the burning of municipal and factory wastes worsened the situation. The haze remained until it was blown away by winds, or 'washed' down by heavy rainfalls.

The first indication of haze during the 1997/98 El Nino episode started in early July 1997. By September, almost all parts of the country were affected by haze, with the Total Suspended Particulate (TSP) registered at more than 100 μ/m^3, compared to that of the long term mean of between 30 - 60 μ/m^3. The highest value recorded was on the 23rd and 24th September 1997, during which TSP values for Kuching reached 1,032.0 and 1,033.0 μ/m^3 respectively (Lim Joo Tick and Ooi See Hai, 1998). The haze episode came to an end in early October 1997.

Based on readings from selected weather stations, there was significant deterioration of monthly air quality in the country. The drop in air quality was due to a significant increase in TSP that had reached an alarming level in almost all regions. As a whole, the increase in TSP during the peak of haze episodes between the months of July to September 1997 ranged from 1.6 fold in Sabah to that of 3.5 fold in Sarawak.

In summary, for all regions of the country, the last El Nino episode resulted in a rainfall deficit ranging between 5 per cent to 26 per cent, an increase in temperature between a 0.5° C to 1.7° C, and air quality, measured in terms of Total Suspended Particulate (TSP) also deteriorated dramatically by 1.6 to 3.5 times the norm.

Climate change and agricultural development

Environmental stresses such as drought, high temperatures, and air pollution are major limiting factors to crop productivity in the tropics. The intensity depends on the severity, duration and time of stress in relation to phonological stages of growth. The two most sensitive stages of growth to stress are during the flowering and early fruit development. Crop productivity decreases linearly with a decrease in rainfall, increase in temperature and a decrease in solar radiation.

Lack of water influences crop growth in many ways. Generally, most crops grow well with a mean annual precipitation greater than 2,000 mm and a minimum monthly rainfall of about 150 mm. Crop productivity decreases with a decrease in rainfall and would severely be affected when mean annual precipitation falls below 1,000 mm. This precipitation requirement is true for many important plantation crops such as oil palm, rubber, cocoa and other annuals such as rice and vegetables. In perennials, such as oil palm, monthly yield depends on climatic conditions 2 to 2.5 years before harvest and the effect of prolonged drought on fruit trees can result in reduced yields for several years. On the other hand, some perennials e.g. mango, durian and mangosteen will not flower properly unless they have been through a period of water stress.

Solar radiation is also an important factor in agricultural production. It controls photosynthesis and has a strong effect on many other biological processes. Photosynthesis and transpiration are two physiological processes that increase almost in proportion to the intensity of solar energy. In general, most tropical crops require the optimum amount of sunshine of about 3-4 hours and yield is not usually affected if the intercepted radiation is more than one third of the full sun energy. Relatively high solar radiation during the reproductive stage has remarkable effects on increasing yield in rice, oil palm and fruit trees. However, a reduction of 40 to 70 per cent in intercepted radiation as the result of air pollutants or with the occurrence of haze may, to a certain extent, affect crop productivity. The reduction in fresh fruit bunch yield and lower extraction rate for oil palm is presumably attributed to haze that occurred within the previous three months.

Socio-economic impacts on selected commodities

This section will describe and quantify the effects and impacts of El Nino induced climate change on selected agricultural commodities of economic importance. The assessment is based on economic losses at three levels; the national level, the regional or state level and the estate or farm level. Whilst the analysis on impacts at the national and regional levels depends heavily on secondary data sources and meetings with relevant authorities, impact assessment at the farm level relied heavily on a series of case studies and personal interviews with the farmers and estate/land development authorities.

Analytical approach

In analyzing the effects of the El Nino on crops, two methodological approaches were used. Where there were sufficient and reliable time series data, a simple production function was used to obtain crop response relationships to a number of variables that were hypothesized to influence crop yields and production. These variables were chosen based on the theoretical foundation of the influence of weather changes and the biological interactions between crop and weather, which were described under the previous heading. This method was applied to Malaysia's three most important crops viz. oil palm, rubber and rice.

The second method was by using the "moving interval maximum" method where a percentage loss in a particular year could be computed, based on a moving maximum for a particular period (Gommes, 1998). This method was also used for oil palm, rubber and rice to complement the production function approach. These approaches were used for the assessment of both national and regional impacts of El Nino induced climate change.

Farm level assessments on impacts was based on 'with and without El Nino' analyses. Whilst these approaches are quite practical among the large estates and land development authorities due to availability of data and information on record, it is not so at the farm level, especially among small farmers. This is due to poor record keeping, or no record keeping at all, among the farmers. This is further compounded by the fact that the last major El Nino episode happened 4-5 years ago. Nevertheless, data and information collected during the primary data collection by personal interview did provide some insights on the socio-economic impact brought about by El Nino.

Impact on the oil palm sub sector

By using the 'moving interval maximum' method, the results of the analysis revealed that the palm oil industry, did indeed suffer significant losses resulting from weather variability at the national level. The 1981 and 1982 episodes of El Nino for example, resulted in an almost 21 per cent loss the following year, while the 1990 episode had resulted in a more than 10 per cent yield loss in 1991. The most severe El Nino episode of 1997 resulted in yield losses of 16.8 per cent. Based on nominal prices of palm oil for the respective years, the gross total loss for the three major episodes amounted to an astounding RM 4.7 billion (Table 2). This value was the estimate only for crude palm oil. The losses would be higher if other palm oil products such as palm kernel oil were considered.

The analyses also indicated that there were high yield losses in 1987 and 1988, which were years without major El Nino episodes. Therefore, theoretically, the yield losses of 1983, 1991 and 1998 cannot be attributed to El Nino alone but could also be attributed to other weather vagaries. To isolate the effects of El Nino and other weather-related variability, the mean yield losses for the "El Nino years" (EY) and the "non-El Nino years"(NEY) were computed (Table 3). Even after subtracting, for all other vagaries, the damage from the El Nino still amounted to 7 per cent. By subtracting the mean NEY loss from the loss in an EY, the net loss from El Nino could be obtained for the year (Table 4). Based on this estimate, the total net loss resulting from El Nino was RM 2.67 billion.

Table 2. Estimated losses for oil palm due to weather variability

Year	Estimated % loss	Production ('000 tons)	Estimated production without variability ('000 tons)	Difference ('000 tons)	Price/non RM	Loss (RM million)
1982	9.18	3,510.92	3,833.22	322.3	829.0	267.18
1983	20.78	3,016.48	3,643.30	626.82	991.0	621.18
1991	10.30	6,141.35	6,773.91	632.56	836.5	529.14
1998	16.80	8,319.68	9,717.38	1,397.71	2,377.5	3,323.06
				Gross total		4,740.56

Source: Author's calculation.

Table 3. Mean yield losses for EY and NEY

Item	Mean yield loss (%)
Mean yield loss for NEY	6.78
Mean yield loss for EY	14.27
Net El Nino effects	-7.49

Source: Author's calculation.

Table 4. Estimated net loss for oil palm sector due to El Nino

Year	Estimated Net % loss	Production ('000 tons)	Estimated production without variability ('000 tons)	Difference ('000 tons)	Price/mt (RM/mt)	Loss (RM million)
1982	2.90	3,510.92	3,595.78	84.26	829.0	69.85
1983	14.00	3,016.48	3,438.79	442.31	991.0	438.33
1991	3.52	6,141.35	6,357.53	216.18	836.5	180.83
1998	10.02	8,319.68	9,153.31	833.63	2,377.5	1,981.96
				Total net loss		2,670.97

Source: Author's calculation.

To further analyze this phenomena, a national production function for oil palm was estimated. The results of the estimation showed that a dummy variable, which was introduced for all the years with major El Nino episodes, was statistically significant at the 5 per cent probability level. TSP was also significant, indicating that the haze significantly influenced oil palm yields. The regression analysis also implied that El Nino had significant effects on oil palm yields. This analysis further strengthened the argument that the net loss of RM 2.67 billion to the palm oil industry can be attributed to El Nino.

Similar analyses were conducted for the Kedah-Perlis region. As a whole, the mean losses of the sub sector during El Nino years for the period 1980 to 1999 were about 10 per cent. However, the mean losses for the non El Nino years were higher, at about 16 per cent. This is in contradiction to the results generated at the national level, as discussed earlier. This implies that the qualitative variable was not significantly different during the El Nino and non El Nino years. It would be most likely that the effect of El Nino per se could not be isolated from the losses resulting from other weather phenomenon. Nevertheless, the estimated losses due to the 1997/98 El Nino alone were estimated at RM 113.2 million.

The rubber sub-sector

To further analyze the effects of weather variability on rubber yield the ‘moving yield maximum’ method was applied to the rubber time series data. The percentage loss from weather variability ranged between zero per cent to 20.28 per cent. Average yield loss for the EY was 7.33 per cent, while average yield loss for the NEY was 4.33 per cent. Therefore, the net El Nino affect was estimated to be 3 per cent. Although the percentage loss could be considered small, the value of the loss can be significant due to the size of production. The magnitude of loss for each of the El Nino years with negative net loss from El Nino was computed using a similar approach as in oil palm (Table 5). Total losses were estimated to be RM 356.75 million.

As for the case of oil palm, a production function based on similar variables was also regressed for rubber yield. However, for rubber, the variables were not lagged since rainfall, temperature and TSP were hypothesized to effect current year yields. Results of the estimation showed that the dummy variable for El Nino years was significant at the 10 per cent level of probability. This indicated that El Nino in some way or another did affect rubber yields.

Table 5. Estimated net loss of rubber sector due to El Nino

Year	Estimated net % loss	Production	Estimated production without El Nino (‘000 tons)	Difference	Price (RM/ton)	Loss (RM million)
1981	1.18	1,452.00	1,469.13	17.13	1,400	23.98
1982	1.53	1,440.93	1,462.98	22.05	1,400	30.87
1990	15.95	1,352.00	1,567.64	215.64	1,400	301.90
					Total net loss	356.75

Source: Author’s calculation.

At the regional level, rubbers performance varies substantially due to weather variability and could affect yields up to 30 per cent. However, the mean losses for the period were almost similar to that of oil palm, at about 15 per cent. As in the case of oil palm, the El Nino phenomena did not significantly affect performance in the Kedah – Perlis region. By isolating the effect of other weather variability, the net loss from El Nino was only about 2 per cent. For the 1997/98 El Nino episode, the loss was estimated at about RM 5.8 million.

The paddy sub-sector

An analysis similar to oil palm and rubber was also conducted on rice yields. Yield loss due to weather variability was between zero and 15 per cent. It can be observed that in the El Nino years of 1990 and 1998, yield losses were quite high. However, high yield losses were also observed for non-El Nino years in 1983, 1984, 1988, 1989 and also 1991. As with oil palm and rubber, losses for the El Nino years and the non-El Nino years were computed to isolate the effects of El Nino from other weather related variables. Results showed that at the national level, the net effect of the El Nino was only – 1.15 per cent. Net losses computed for the rice industry were estimated to be about RM 218 million (Table 6). However, this value is inclusive of the value of the subsidy by the government. Minus the subsidy the actual loss in nominal terms was lower at RM 158 million.

Table 6. Estimated Net loss of rice due to El Nino

Year	Estimated % net loss	Production	Estimated production without El Nino ('000 tons)	Difference	Price (RM/ton)	Loss (RM million)
1981	4.0	1,748.77	1,818.72	69.95	511.85	35.80
1980	1.8	1,884.98	1,918.91	33.92	660.00	22.38
1998	5.66	1,994.24	2,107.11	112.87	1,413.85	159.58
				Total net loss		217.76

Source: Author's calculation.

A regression analysis similar to palm oil and rubber was also undertaken for rice. The results showed that although the El Nino years per se, did not affect yields (insignificant dummy), TSP appeared to be a significant factor that affects yields. All other variables were not significant except for rainfall, which is only significant at the 10 per cent probability level.

The impact of an El Nino episode on paddy production at the regional level was more pronounced than that of oil palm and rubber. Total mean loss due to weather variability was 8.45 per cent. Being an annual crop, which is more water dependent, the level of water during the critical growth period had negatively impacted yield levels within the same season. Net losses due to weather variability were estimated to be 1.59 million tons during the 1980-1999 period. For 1997 alone, the El Nino episode resulted in losses totaling RM 23 million, excluding the price subsidy component.

Fruits, vegetables and others

Measuring the actual impacts of El Nino on fruit yields is rather difficult due to the aggregate nature of the data. Yields in this case, are the average yields of all fruits that are recorded. There are at least 15 fruit types that are included in the statistics. The hectarage and production of each fruit type in each year is not in constant proportion and therefore, a simple mean might not be a good indicator of the actual means, which should be the weighted average. However, data on an individual fruit-crop is not available to enable a computation of the weighted means. Additionally, there are no records of matured and immature fruit areas. As such, the mean yield computed is not reflective of the productive areas under fruits. This biasness in calculating the mean yields for the respective years might led to biasness in estimating yield loss due to weather variability.

Based on the analysis, the mean yield loss for the NEY was 10.84 per cent while for the EY, the computed mean was 11.07 per cent. Therefore, the net affect of El Nino is only - 0.23 per cent. Hence, El Nino is not the main weather-related factor that caused yield loss in fruits. Other weather or non-weather-related phenomena might be more important than El Nino in affecting productivity in fruits.

Estimating the affects of El Nino on vegetable yields also faced similar constraints as in the case for fruits. The main yield of vegetables for the 1982 – 1999 period is highly erratic. It ranges from as low as 5.75 tons per hectare in 1989 to as high as 19.71 tons per hectare in 1983. This erratic nature of mean yield also led to wide variations in the estimated yield loss due to weather variability, which ranged from zero per cent to 67.46 per cent. The mean yield loss estimated for EY and ENY years showed that yield loss during EY was much lower than NEY. This indicated that it is unlikely that El Nino had any major influence on vegetable yields. This finding is quite acceptable considering that almost all vegetable growers irrigate their crops.

For other agricultural commodities (sugarcane, tobacco, marine fish and aquaculture, livestock products), it appeared that their production levels were not affected during the El Nino episodes. Their pattern of production did not show any significant relation brought about by the El Nino induced climate change.

Farm level impacts

Due to data limitation, especially among the small farmers, the assessment on the impact of El Nino induced climatic change at the farm level would be limited on assessing the changes that had taken place on the farm during the 1997/98 El Nino episode. At the estate level, these include changes in the production and productivity level between a normal year and the El Nino years. The implication on working days and farm income are also noted. Among the small farmers, and considering the unavailability of data between years, the assessment would be very much qualitative in nature. A summary on the farm level impacts is as follows:

a. *The oil palm estate*

The resultant water stress, especially in the year 1997, resulted in a significant reduction in productivity. In fact, between the years 1994 to 2001, the productivity level for 1997 was the lowest at 17.5 mt compared to the average yield of the period at 21.1 mt/year; a reduction of about 17 per cent. However, there was no impact on the income of the farmers since most of the workers were paid monthly fixed wages. For the other 'hired hands' such as the harvesters, they were paid based on the task given, usually on a per hectare basis.

b. *The centrally managed rubber smallholders scheme*

The prolonged drought during the El Nino episode resulted in the highest number of tapping days during the period 1991 to 2001. For the 1997 episode, there was an increase in tapping days of up to 261 days compared to the average tapping days of 244 on the estates. Accordingly, this resulted in the achievement of a yield level at 1.8 mt, the highest level recorded compared to the average yield of 1.47 mt/year for the period. This is an increase of about 22 per cent. Consequently, this contributed positively to the income of the rubber tappers during El Nino years. The average monthly income of the rubber tappers stood at RM 1,474. Productivity, however, declined to 1.4 mt and 1.2 mt for the years 1998 and 1999 respectively. In terms of income, the levels declined to RM 1190 and RM 823.

c. *The sugarcane plantation*

Overall, the El Nino episode resulted in some positive impacts to the plantation. Whilst the water stress brought about by the prolonged drought had resulted in the lowering of yield, this was compensated by the higher sugar content. This could be seen in yield records registered by Felda Chuping Sugarcane Plantation, where the yield level achieved in the 1997/98 period was the lowest ever recorded by the plantation, at 47.9 mt/ha against the normal yield level of above 60 mt/ha. The second lowest yield level registered was in 1991, with yield level at 53.1 mt/ha. However, during these two periods, the TC/TS ratios (the recovery rate which indicates the amount of sugarcane required to produce sugar) was 10.9 and 10.1 respectively, which is lower than the normal rate of about 11.4.

d. *Small* paddy farmers in MADA irrigation scheme

About three-quarters of the paddy cultivated areas in the region are within the MADA area. Hence, the earlier write-up on the affects of El Nino on paddy production in the region is also applicable at the irrigation scheme level. The only difference is the fact that farmers within the irrigation scheme are less exposed to the vagaries of water shortages compared to that of areas outside the scheme. Nevertheless, at the scheme and farm levels, there were some changes that could be attributed to the El Nino episode.

The mean annual yield level in MADA for the period 1980-1999 was about 4 mt/ha. The El Nino years of 1983, 1986, 1987, 1991 and 1997 registered yield levels below this average value. In addition to the declining productivity due to water stress at the farm level, the El Nino episodes also led to total farm losses, with zero yield. This was in evidence during the 1982, 1987, and 1997/98 episodes where a total of 16,088 hectares of paddy land registered total loses due to drought incidence. The actual losses at the farm level are difficult to assess due to poor record keeping and memory.

e. Fruits, vegetables, fisheries and livestock

Again, these activities are carried out mostly by small farmers, hence the poor availability of records. Attempts to quantify the impacts of El Nino induced climate change among these groups of farmers are not possible. The small farm size, the part-time nature of farming activities and the capacity to change quickly the crop types in view of the coming El Nino or drought, contributed to the insignificant affect of El Nino episodes on them.

Risk management and coping mechanisms

These represent the institutional preparedness and management strategies to mitigate or reduce the impact of El Nino induced climate or weather change on the agricultural sector. In fact, the marginal impact of climate variability on some of the crops in this country could be attributed to the various mitigating measures already in place. This is especially so with annual crops, where crop management in terms of crop care, crop choice and crop scheduling are more flexible as compared to that of perennial crops.

Climate monitoring and forecasting

In Malaysia, the main agency responsible for the monitoring and forecasting of climate variability is the Malaysian Meteorological Service (MMS), which provides national meteorological services in climatology, agro meteorology, hydrometeorology, seismology and atmospheric pollution. It has an extensive network of meteorological observation stations throughout the country, with round the clock weather surveillance.

Specifically in relation to El Nino incidence, MMS monitored its development and evolution by keeping track of the Southern Oscillation Index (SOI) and other information from the various climate prediction centers around the world. This data was used to predict short-term climate variation for the country. These predictions are distributed to the relevant authorities in the country, both at the national and state levels, and used fairly extensively especially with regards to water resource management.

Water resource management

The last El Nino episode showed that the country as a whole experienced water supply strains, albeit at different degrees of seriousness. This was due to the prolonged drought, at the same time as when the demand for water supply to support the requirement for households, industry and agricultural purposes had been on the rise. Therefore, any mitigating measures to address the problems associated with water shortages and deficiency must take into account how well the existing water resources are managed.

Within the agricultural sector, and especially in the major irrigation schemes, efforts to ensure efficient and judicious use of irrigated water, especially during the time of rainfall deficits have been on going. Several measures have been taken within the irrigation schemes to continue to upgrade water use efficiency at all irrigation schemes and avoid unnecessary wastage. Some measures which have shown to be effective, especially in the Kedah-Perlis region, are as follows:

a. *Water Management and Control Scheme*

The system was operationalized in 1998 in the MADA irrigation scheme, with the purpose of optimizing the limited amount of stored water and other resources by accurate and timely assessment of the supply and demand of the water (Low Kean Leng, 1996). It is a decision making tool capable of real time reporting of rainfall distribution and strategic water levels in the dam and the irrigation canals. This information is used in deciding the reduction of down release from the dam to the irrigation canals, reallocation of water within the scheme etc. Basically the system computes daily water demand for each irrigation block and subsequently the amount of discharge required. The major component of the system is the mainframe computer as host for all data processing and central depository, 67 telemetric rainfall stations and computer terminals linked to the host computer and VHF radio channels for voice communication.

b. *Irrigated water recycling*

As part of the water conservation strategy, water-recycling activities were introduced within the MADA irrigation scheme. Under this approach, water demand from the dam for rice cultivation could be reduced. Through this mechanism, excess drainage water from the rice fields is captured and instead of going to the sea, the water in the drainage canal is put back into irrigation canals for reuse by a single or series of pumps. Currently, there are 22 pump houses and 685 mobile pumps in place for this purpose. About 5 per cent of the total water requirement in the scheme was contributed from this source. The quality of the recycled water is comparable to that of irrigation water. In fact, there were cases of yield improvement due to the usage of recycled water (K. Sani *et al*., 1992). In the long run, as water use efficiency increases, the amount of water available for recycle purposes will decline.

c. *Water 'pounding' technology*

A simple, indigenous technology on water management was practiced on the sugarcane plantation. Since all the sugar plantations are located in drought prone areas in the northwestern part of Peninsular Malaysia, where severe droughts occur almost routinely every four to five years, all the plantations are equipped with irrigation systems. The water sources are derived from the many small and scattered man-made lakes, made possible by damming small creeks in this hilly and undulating topography. The 'storage' water is sufficient to irrigate the field, by using a mobile sprinkler system. The system was found to be very reliable, it is cheap and easy to maintain. When the need arises, more 'lakes' can always be constructed.

Research and Development

Research and Development activities, as a means to address issues related to changes in climatic parameters have been carried out as an on-going activities in this country. The more prominent achievements are as follows:

a. *Development of short maturating variety*

Malaysia has been successful in developing a number of short maturating varieties. These varieties are grown very extensively in almost all rice growing areas. With the maturation period of between 115 to 135 days, this would ensure less water requirement as compared to the earlier, long maturation varieties. A shorter rice season would mean less risk and exposure to environmental hazards, be it in the form of drought or floods.

b. *Development of drought resistant paddy varieties*

The Malaysian Agricultural Research and Development Institute (MARDI) keeps a gene bank, where genetic resources which represent the stock from which genetic diversity is obtained for breeding programs. The collection, preservation and maintenance of a broad spectrums of rice germplasm, currently totaling about 8,000 accession, are used as the source of breeding activities, including the development of drought tolerant varieties. Through the on-going rice varietal development program, the breeding and selection of new varieties with the objective of developing high yielding varieties to suit different rice environments has been carried out, including for drought prone areas.

c. *Water saving technologies*

New and improved procedures for on-farm water management have been formulated and developed. To minimize water use at farm level, improved cultural practices have been introduced which would optimize water use efficiency, whilst reducing water loss and wastage. Understanding of system behavior between plant and water, alternative irrigation scheduling techniques, rainfall-run off analysis, water use efficiency and infield distribution, seepage pattern, dry rotation and dry seeding, and assessing the environmental effects of drainage water recycling are some of the R&D activities which have been undertaken. Relevant technologies have been adopted and used in irrigation schemes.

For the perennials, focus was given to improving and promoting newer irrigation techniques, such as drip irrigation, which had been extensively used by the farmers in drought prone areas, especially during the planting and establishment period. This is very prevalent in fruits production. Production of other annuals, other than rice, has always been supported with irrigated water, either from rivers or swamps, as well as underground water.

d. *Precision farming*

As a new concept under study, the system would ensure the correct usage of resources, including water resources, toward achieving greater farm productivity. In essence, the system will ensure efficient utilization of production input resources, including water resources in rice production.

Zero burning technology

One of the most prominent achievements so far on reducing the incidence of haze was the introduction of zero burning technology during the replanting operation, especially in oil palm plantation. Traditionally, oil palm trees are cut down and burned. This was found to be cheap, practical and effective. Through zero burning, old oil palm trees are felled and cut, piled and let to rot in the field. This reduces the possibility of haze formation since no burning of biomass is taking place, and the rotting palms can provide an additional source of organic matter to the growing palm trees. This practiced has been extensively used in the country, with full support by the government and plantation sectors.

Other policy measures

a. *Economic diversification and income support program*

There is a need to diversify the sources of income among the resource poor farmers away from the agricultural sector. An over dependence on the agricultural sector, especially in the sector where they are more expose to the risks brought about by El Nino induced climate change must be avoided. Currently, the poverty level is the highest in the agricultural sector, where about one quarter of all rice farmers and one-fifth of rubber tappers are within the poverty group. In this respect, the current efforts by the government to diversify and improve the farmers' incomes by the introduction of specific programs are commendable. Under the current 'Development Program for the Poorest', the farmers are provided with direct income support as well as financial and other supportive measures to encourage their involvement in economic activities other than agricultural activities. The availability of other employment opportunities in manufacturing and the services sector within their vicinity will support this move. Additionally, the introduction of the Micro Credit Scheme opened up new avenues for income earning opportunities among these resource poor farmers.

b. *Strengthening of Environmental Acts and Regulations*

The Environmental Quality Act (1974) was amended to provide stricter regulations and stiffer penalties to ensure, among others, the maintenance of air quality in the country. The Department of the Environments is custodian to this. Relatedly, the monitoring and subsequent enforcement has been stepped up. Through the amendment in the Act, open burning is prohibited except for such activities that may be prescribed by the Minister, as published in the gazette. The penalty for contravening was substantially increased to RM 500,000 or imprisonment not exceeding 5 years, or both. In line with the stiffer penalties, enforcement activities were stepped-up whereby ground enforcement teams were mobilized throughout the country to check on open burning activities. An operation control center was established to receive reports and coordinate enforcement actions. Additionally, aerial surveillance was conducted to enhance and strengthen ground enforcement as well as to verify information from satellite imageries detecting 'hot spots' in the country for further enforcement action or other mitigating measures.

c. *Development of National and Regional haze Action Plan*

National Haze Action Plan (NHAP) prescribes the operational procedures in response to the different levels of API. Under the Action Plan, continuous preventive measures have been introduced to detect early the outbreak of fires, including aerial surveillance in fire prone areas such as in the plantations, peat swamps, and construction sites. The formulation of national strategies and response plans to control and mitigate the impacts of haze are undertaken by this action plan. However, once the API value reached 300 and above, the Action Plan is coordinated by the National Committee on Disaster Relief and Management (Department of Environment, 1999).

Following the 1997 regional haze episode, a response strategy in the form of the Regional Haze Action Plan (RHAP), was introduced. The plan is suppose to complement and support the individual National Haze Action Plan. The aim of the plan is to establish close cooperation among ASEAN countries to prevent the occurrence of haze in the region arising from land and forest fires. It spelt out the requirement of mechanisms that will enable authorities in the region to prevent fire, spot those that occurred quickly and take action to prevent them from spreading.

d. Cloud seeding

As part of a short-term measure to combat drought and haze in the country, the Malaysian Meteorological Services conducted several cloud seeding operations to enhance rainfall over the catchment areas. This can also help in ‘cleaning’ the polluted air during the haze period. Such operations are carried out, especially during the peak of El Nino episodes when water levels in the dams are at a critical stage. Similar operations were conducted to improve the irrigated water supply in MADA rice irrigation scheme.

e. Introduction of El Nino/Drought Action Plan

Whilst drought incidence is not one of the major ‘disasters’ facing the agricultural sector, the development of a drought action plan would be helpful in time of severe drought incidence. The current initiative by the government to develop an El Nino Action Plan is commendable and very timely. This effort should be able to establish ‘mechanics’ to ensure greater coordination and implementation of efforts to reduce the impact of El Nino.

f. Contingency Aid Schemes For Affected Farmers

The previous El Nino episode caused adverse effects for some segments of the farm community. Specifically, the significant reduction in income received by oil palm growers because of yield reduction, and the total failure of rice fields due to drought, albeit on small scale, warrant the introduction of some contingency plans. A government-sponsored scheme to provide some aid to the affected farmers so as to protect their livelihood and welfare during such episodes are already in place, albeit on an ad hoc basis. The introduction of crop insurance, which at the moment is not very widespread, should be able to provide some level of income-security to the farmers.

Conclusion

This paper has highlighted some of the El Nino induced weather vagaries that have taken place in previous El Nino episode. Generally, there was a significant reduction in rainfall, a general increase in temperatures and a significant deterioration in air quality. This climatic variability has been shown to affect crop productivity and hence, crop productions. From the analyses carried out, there was strong evidence to show the negative effects of El Nino on Malaysian agriculture, from the national level perspective to the regional level, and finally at the farm level. Whilst some of the risk management strategies in place have already yielded some benefits in mitigating or reducing the impact of El Nino induced climate change on the agricultural sector, many more need to be implemented. This is especially so in areas where food security is under threat, and the income of resource poor farmers is in jeopardy.

Without doubt, El Nino is here to stay. The possibility of increased frequency and magnitude in the future is real. Relatedly, the impact on the economy as a whole, and to the agricultural sector specifically, could be more adverse than what was in the past. It is pertinent now that more affirmative measures be introduced and implemented so as the impacts can be mitigated as much as possible and the sooner the better. The sharing and working together among the affected countries or communities in facing the future El Nino episodes is definitely a step in the right direction.

References

Ariffin Tawang, Tengku Ariff Tengku Ahmad and Mohd Yusof Abdullah, 2002. In Stabilization of Upland agriculture under El Nino Induced Climatic Risk: Impact Assessment and Mitigation Measures in Malaysia. Working Paper No 61, Bogor, Indonesia: CGPRT Center.

Lim, J.T, 1998. ENSO and its relationship to haze and forest fire in Southeast Asia, Malaysian Meteorological Services, Petaling Jaya, Selangor, Malaysia.

Lim, J.T. and Ooi, S.H., 1998. Effects of biomass burning in Southeast Asia on meteorological condition in Malaysia. Paper presented in the conference on weather analysis and forecasting, Taipei, Republic of China, 23-25 February.

Gommes, Rene, 1998. Climate-related risk in agriculture. A note prepared for the IPCC Expert Meeting on Risk Management Methods, Toronto, Canada, 29th April – 1st May 1998. Malaysian Palm Oil Board. 2001. MPOB Homepage @ http://www.mpob.gov.my

Sani, K., Mashhor, M., Ayub, M. and Puat, N.A., 1992. Recycling of drainage water for rice irrigation in the Muda region, Kuala Lumpur: MARDI.

Department of Environment, 1999. Environment Management-Zero burning. Ministry of Science, Technology and the Environment, Malaysia: Department of Environment.

Low Kean Leng, 1996. Management information system for the Muda irrigation scheme in Malaysia. International Commission on Irrigation and Drainage, Sixteenth Congress, Cairo.

Comments on the Malaysian Country Report with Specific Reference to the Muda Irrigation Project Area

Wong Hin Soon[*]

Introduction

The paper written by Mr. Ariffin Tawang has clearly indicated that the El Nino events recorded in 1982/83 and 1997/98 have significantly affected production in the agricultural sector in Malaysia, in particular the oil palm, rubber and paddy sectors. This is caused by El Nino delaying monsoon rains, resulting in abnormally dry weather conditions and an increase in daily temperature, plus an increase in forest fires which brought about haze in the atmosphere. Mr. Ariffin has also attempted to quantify the magnitude of the losses for Malaysia as a whole and for the regional and farm level, particularly for the case of paddy in the Northwestern region of Peninsular Malaysia. My comments will be limited to the latter part of his study, particularly on the paddy growing region of the Muda Irrigation Project area.

Background

The Muda area covers a total of 126,000 hectares of the coastal plain of the states Kedah and Perlis and paddy is grown as a monocrop with a total planted area of 96,000 hectares operated by 63,000 small farms. The project started in the 1960s with the construction of dams and irrigation facilities which have successfully enabled double cropping of rice to be practiced since 1970. The region is considered to be the rice bowl of the country, contributing 40 per cent of the nation's rice production. The region has a distinct annual dry season, unlike the rest of the country, and this lasts from the months of December to March each year.

The region as a whole is also a water-short region. A study, carried out by Japan International Cooperation Agency (JICA) in 1995, conducted a simulation of the water supply facilities in the region and concluded that the Kedah River system which runs through the Muda project area will experience water deficits once every 3 years. Therefore, any shortfall in rainfall brought about by El Nino or otherwise will have serious implications on the availability of water for paddy cultivation in the area.

Impact of El Nino

Mr. Ariffin's analysis shows that the losses in the Malaysian rice industry due to El Nino in the years 1981, 1990 and 1998 were -1.15 per cent which is translated into a total loss of RM218 million. The impact on the regional level was more pronounced. Total net losses due to weather variability in the Northwestern region was estimated to be 1.59 million tons during the

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1980-1999 period with the 1997/1998 episode alone resulting in losses totaling RM101 million, although no estimate was given for the effect of El Nino alone.

The El Nino phenomenon is characterized by low rainfall and has impacted the water resources in the Muda region. The result of low rainfall in the paddy growing areas of the region is manifest in the water supply in the irrigation dams which has to increase water releases to offset the low rainfall. This is shown in the condition in the Pedu Dam which is the major dam for irrigating the paddy fields in the region, during the beginning of the irrigation season on 1st March of each year, which shows corresponding low levels of water during the El Nino years of 1977/78, 1982/83, 1986/87, and 1991/92 (Table 1). During the more recent El Nino years of 1994/95 and 1997/98, water levels were more healthy, and this may be due to a certain extent, to water conservation measures instituted by MADA (Muda Agricultural Development Authority, the controlling agency for the dams) as explained below.

Table 1. Irrigation schdule, water level of Pedu Dam and rice yield

Year	Start of Irrigation	Amount of Water Storage (acre feet)	Gross Rice Yield (kg/ha)	Remarks
1980	15/02/80	329,000	4,538	
1981	15/02/81	369,000	4,401	El Nino
1982	01/04/82	98,000	3,267	El Nino
1983	15/03/83	342,000	3,123	
1984	01/03/84	604,000	3,246	
1985	15/02/85	564,000	4,018	
1986	01/03/86	418,000	3,783	El Nino
1987	No schedule	304,900	2,663	El Nino
1988	01/03/88	641,900	3,182	
1989	01/03/89	848,300	3,767	
1990	10/03/90	516,600	4,133	
1991	No schedule	145,200	3,864	El Nino
1992	18/05/92	470,900	3,761	El Nino
1993	22/04/93	398,800	4,284	
1994	26/03/94	655,600	4,486	El Nino
1995	18/03/95	687,800	4,575	El Nino
1996	18/03/96	771,900	4,769	
1997	04/03/97	893,600	4,435	El Nino
1998	05/03/98	866,600	4,455	El Nino
1999	15/03/99	883,400	5,010	
2000	05/03/00	876,300	4,936	
2001	15/03/01	876,900	5,214	
2002	25/03/02	756,600	n.a.	El Nino

Source: MADA.

El Nino in 2002

This year, 2002, the El Nino phenomon struck again. Although nationally, the severity has been described as mild, in the rice growing region of the Northwest, it has been marked significant. In Table 2 below the amount of rainfall this year is significantly less during the first 8 months compared to the 66 year average from 1935-2001.

Table 2. Comparison of rainfall in 2002 against 66 year average

	Jan	Feb	Mar	April	May	June	July	Aug	Total
2002	3.8	21.2	60.6	274.2	66.6	156.8	242.2	165.4	990.8
Average	38.0	54.0	121.6	206.8	228.8	161.8	192.8	216.0	1219.8

Source: MADA.

In addition to this 20 per cent reduction in rainfall, the pattern of rainfall has also changed. Daily rainfall records in the Kepala Batas rainfall station at the center of the Muda area shows one period in which no significant rain fell for 26 days during the months of May and June. This corresponded with the critical plant growth period and MADA was forced to counteract this with excessive dam release of irrigation water. Total irrigation supply during this season showed a significant increase on the average. The total amount of irrigation water released this season was 580,429 acre feet compared to the average of 407,612 acre feet. The end result is the present low water levels in the dams which may affect irrigation for the next few seasons if it is not compensated by heavier than usual rainfall at the dam catchment areas in the next few months.

Water conservation measures in Muda

Mr. Ariffin has eloquently described the mitigating measures taken by the Government of Malaysia and its agencies to counter the effects of El Nino. This commentary is confined to further reinforce and underline the efforts undertaken by the Malaysian government at the regional level in the Northwestern part of Peninsular Malaysia where paddy is the main crop. Planting of paddy here, particularly in the Muda area, depends greatly on rainfall in spite of the 3 dams built for irrigation. Only 29.5 per cent of the water requirement is met by irrigation water. The bulk of the water requirement is for paddy planting and 52.2 per cent comes from rainfall. The balance comes from re-cycling drainage water and water from rivers downstream of the dams. As such, the region is very sensitive to changes in the weather patterns as experienced in the past. MADA has therefore instituted many water conservation measures to counter the effects of weather changes due to El Nino or otherwise.

Re-scheduling of water supply

One of the major decisions MADA had to take during years when water levels in the dams were insufficient to start the irrigated crop was whether to irrigate the fields or not. For equity and political reasons, MADA found it prudent not to practice rotational irrigation. Instead, once it decided to start irrigation, it was compelled to ensure the crop had enough water. Therefore, during the last 25 years, MADA had to make the decision not to officially start off season irrigation. This was during the El Nino years of 1978, 1987 and 1991. During these years, farmers were advised to withhold planting until the rains came and to practice dry ploughing and dry direct seeding. In this way, water was conserved and only supplementary irrigation was given during the season. The vast majority of farmers were able to successfully see the crop through, although with reduced yields. On other occasions MADA delayed the start of the irrigation. This was evident this year when the start of the off season crop was delayed by 10 days in anticipation of rainfall. Simulation of the water supply situation in the dams shows that with this delay, a total of 46,880 acre feet of water was saved in the dams.

Water control and management system

In response to the critical water shortages experienced in the region, which was compounded by El Nino, MADA instituted a project to monitor rainfall and water conditions, water usage and maximize rainfall utilization. This took into account the fact that water released from the dams took 2 to 3 days to reach its targeted destination in the fields. In the meantime, rain could have fallen and rendered the release academic. This project involved the installation of 80 rainfall stations within the paddy areas as well as the dam catchment areas. In addition, 13 river stations were installed at rivers downstream of the dams. Data from these sites is transmitted in real time to the Control Center in MADA headquarters. At the same time, readings of water levels in selected paddy fields in every irrigation block are transmitted to the Center weekly and computer calculations are made daily on water requirements in each block. Appropriate instructions are then made regarding dam water releases. Through this project, significant savings are made to water supplies. This system is being further refined and upgraded through increasing the number of monitoring stations.

Regulating ponds

The ponds are planned to be constructed at a site before the irrigation waters released from the dams reach the project site. The justification for this is the long distance between the dams and the paddy fields. Water released from the dams will be diverted into this regulating pond to minimize water wastage should rain fall from the time of dam release to the time it reaches its destination. Water from this regulating pond could also be released to meet irrigation needs and avoid dam releases.

Recycling

Recycling water from drains now contributes 5.4 per cent of the total water requirement and this will further be enhanced as more sites are identified.

Agronomic practices

Present water utilization by the paddy crop is high. The most wasteful practice is wet seeding whereby fields are flooded and then subsequently drained before seeding. Research and development is being conducted to change this practice to prevent water being wasted. Dry ploughing and dry seeding technology is being tried and encouraged to be practised. Also under investigation is seeding under flooded conditions.

Water use efficiency

Present irrigation use efficiency could be increased further through proper bund management, irrigation practices and the establishment of water user groups. Included in this category are the establishment of group farms and paddy estates.

Review of irrigation facilities

The present irrigation and drainage intensity in the Muda area is 11 meters per hectare in 70 per cent of the area and 35 meters per hectare in the other 30 per cent. An ongoing project is being implemented to bring the entire area to 35 meters per hectare with tertiary irrigation facilities. MADA is presently reviewing this project to determine the actual intensity required in light of present attempts to encourage large-scale cultivation of paddy through group farms and paddy estates. Research findings also indicate increasing water wastage with a corresponding increase in drainage intensity.

Cloud seeding

Cloud seeding has been carried out from time to time in response to critical water situations in the country. In the Muda area, several attempts have been made to encourage precipitation of rainfall over the catchment areas of the dams to help boost water levels. This has been met with mixed results. This year, cloud seeding is to be carried out again from the end of September for a couple of months. This exercise is however, dependent on the availability of suitable clouds over the targeted areas for seeding.

Research and development

Research and development is ongoing whereby MARDI, the Malaysian Agricultural Research Organisation, conducts rice breeding programmes to develop drought resistant and shorter term varieties as part of its genetic pool material. In times of drought and water shortages, these varieties could be planted, as happened in 1987 when water was not released from the dams and the variety IR42, which is shorter term and more suitable for the prevailing weather conditions, was distributed for planting.

Conclusion

The Muda Agricultural Development Authority recognizes the potential impact and damage of El Nino induced climatic changes, especially its effects on rainfall, and appreciates the work conducted by Mr. Ariffin Tawang. It has started taking mitigating measures to minimize these effects on paddy production. With judicious implementation of these measures, and the use of stored water in the 3 dams, water shortages during an El Nino year may be minimized. However this may be at the expense of future years irrigation due to the depleted water levels in the dams as may be happening this year.

Indigenous Drought Coping Strategies and Risk Management in Papua New Guinea

Sergie K. Bang and Kud Sitango[*]

Summary

Papua New Guinea needs to have a National Agricultural Drought Mitigation Strategy against El Nino induced droughts. Since 1910, there have been 11 El Nino induced droughts, none as widely documented as the one in 1997. As global climatic changes make it a frequent threat, new and indigenous coping strategies need to be documented and widely used.

Six worst drought (and frost) hit districts in PNG were surveyed to document indigenous coping strategies and to determine if people in some districts were coping better than others. They are Bogia and Raikos districts in Madang Province, Bena in Eastern Highlands Province, Gumine in Simbu Province, Tambul in Western Highlands Province and Kandep in Enga Province. The main parameters assessed were agricultural production, family income, water supply for household use, bush/famine foods eaten, migration, food aid received, human health and infrastructure and government services during the drought period. In this report, the first 5 parameters are assessed.

Yields of all food crops were reduced significantly during the drought. Sixty (60) per cent of respondents in all 6 districts earned an income through sales of livestock and food and cash crops. Over 40 per cent of respondents saved planting materials for rehabilitation, with the respondents from Tambul and Kandep districts saving only seeds. The majority of respondents in all districts carted water for household use while a few used bamboo piping and one village in Bogia had a well. Respondents reported more energy bush foods (yam and taros) in the Bogia/Raikos and Bena/Gumine districts and only leafy vegetables (ficus and rungia) in the wild in Tambul/Kandep districts. This is partly why respondents of Tambul/Kandep districts reported the highest (39 per cent) migration, in search of food.

The study suggests the inhabitants of Tambul/Kandep (high altitudes) are most at risk, followed by those in Bena/Gumine districts. (mid - altitude). The inhabitants of Bogia/Raikos districts (lowlands) are least at risk. The outlook for the vulnerable districts is not good, unless on-farm contingency plans, both short and long term, are adopted. An On-Farm Coping Strategies Document is available from the National Agricultural Research Institute. The document recommends coping strategies for the pre, mid and post stages of drought as well as ongoing or long term (adaptive) strategies.

Introduction

Analysis of rainfall records for Papua New Guinea from 1910 to 1982 shows that severe droughts have occurred across the country. El Nino induced abnormal weather has occurred in the past at different frequencies and intensities but the 1997 event was described as being the worst in the 20th century. The combined effects of drought and frost led to widespread food and

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water shortages across the country. There was an increase in human diseases, related to food shortages and water contamination and pests and diseases on food crops. Approximately 40 per cent of the rural population (1.2 million people) were starving towards the end of 1997 (Allen and Bourke, 2001).

The final goal of this CGPRT project is to stabilize upland agriculture for further rural development in El Nino vulnerable countries. In Phase 1, the project assessed the impact of the 1997 El Nino induced drought on agricultural production and the rural economy. In the second Phase, a study was conducted on the institutional preparedness to cope with future El Nino induced risks in agriculture. Although people suffered shortages of food and water, each community had various coping strategies. This paper documents these indigenous coping strategies used by six vulnerable areas in the highlands and lowlands of PNG.

Summary of report on impacts of drought (Phase 1)

Severely affected provinces in 1997 were Madang, Markham in Morobe in Momase, Manus, New Ireland and North Solomons of the New Guinea Islands Region, Milne Bay, Central Province, Gulf Province and Western Province of Southern and all of the 5 highland provinces. There were severe shortages of food and water, with garden produce declining by 80 per cent (AusAid Report, 1998) and 40 per cent of the rural population (1.2 million people) were starving towards the end of 1997 (Allen and Bourke, 1998). Typhoid and dysentery were common among the rural population and a lot of rural-urban and rural-rural migration was reported. What saw a lot of people pull through the famine period was the social support system (the wantok system) and abstinence of socio-economic obligations. All efforts were devoted to sustaining their lives.

Government response was slow and inadequate, partly because there was no advance warning of drought. AUSAID mounted a food relief and seed distribution program and was complimented by food aid (rice) from Japan. Aid Delivery by NPOs included mainly food, health services and crop seeds for rehabilitation.

There was a significant reduction in exports of minerals and oil and commodity tree crops in 1997 compared to 1996. The largest disparity was in copper, oil, rubber and tea. Copper exports dropped by 39 per cent and crude oil by 29 per cent, while exports of rubber and tea plunged by 35 per cent and 30 per cent respectively. On the other hand, coffee exports declined by only 5 per cent in the drought year and in fact, increased by 34 per cent in 1998. The trade of highland fresh produce to Port Moresby dropped by 13 per cent in 1997.

El Nino induced droughts and normal droughts in PNG

Drought years can be defined statistically as the lowest 5 per cent or 10 per cent of the driest years at a location (Rainman International, 2002). It is abnormal dry weather when rainfall is below a critical level (median) and persists long enough to produce a serious hydrological imbalance, during which time agricultural production is adversely affected. The severity of the drought depends upon the degree of moisture deficiency, the duration and the size of the affected area (Maiha, 2002).

Generally for PNG, El Nino induced droughts have come about as a result of the warming of the eastern pacific sea (sea surface temperature) and a corresponding decrease (negative phase) in the SOI (Rainman International, 2002). The driest recorded 12-month periods (since 1950) in the equatorial regions of the Pacific were associated with strong negative SOI values. This is referred to as abnormal inter-annual climate variability. The ENSO phenomenon influences this annual climate variability within PNG climate (Maiha, 2002).

On the other hand, a normal drought could be described as an extension of the normal dry season where rainfall is less than the evapo-transpiration rates of crop plants.

History reveals that PNG has experienced 11 droughts since 1910. Of these, El Nino induced moderate droughts occurred in 1965/66, 1976/77/78, 1986/87/88 and 1991/92/93/94. Severe El Nino induced droughts were reported in 1972/73, 1982/83 and 1997/98 (PNG NWS, 2002). Other drought years recorded are 1914, 1931, 1940/41 and 1957/58, but it is unclear whether these were induced by El Nino.

Drought vulnerability in PNG

Drought definition

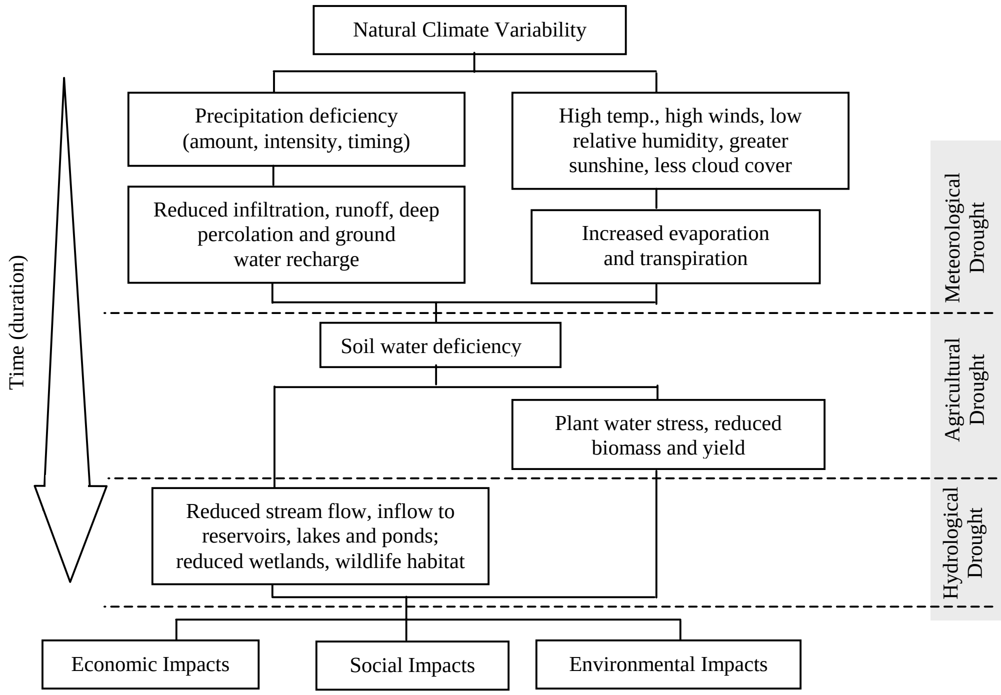
A drought is most often defined as a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield.

It is actually a deficiency of precipitation from the expected or "normal" that, when extended over a season or longer period of time, is insufficient to meet demands. This may result in economic, social and environmental impacts. It should be considered a normal, recurrent feature of climate. Drought is a relative, rather than absolute, condition that should be defined for each region. Each drought differs in intensity, duration, and spatial extent.

There are four perspectives on drought: meteorological, agricultural, hydrological, and socio-economic. Meteorological drought is usually defined by the measure of the departure of precipitation from the normal and the duration of the dry period. Agricultural definitions refer to a situation in which the moisture in the soil is no longer sufficient to meet the needs of crops growing in the area. Hydrological drought deals with surface and subsurface water supplies (such as stream flow, reservoir/lake levels, ground water). Socio-economic drought refers to the situation that occurs when economic goods associated with the elements of meteorological, agricultural and hydrological drought fail to meet the demand. These perspectives or operational definitions help people identify the beginning, end and degree of severity of a drought. Figure 1 illustrates these perspectives of droughts.

Agricultural drought, a period of abnormally dry weather during which rainfall is below a critical level and extends over a certain period resulting in major adverse impacts on agricultural production, is of more importance to us at present. It is an extended period where precipitation is less than evapo-transpiration.

Figure 1. Perspectives of a drought



Source: Rainman International, 2001.

Vulnerable provinces

Vulnerability

Vulnerability of a location refers to the characteristics of populations, activities, or the environment that make them susceptible to the effects of drought.

The degree of vulnerability depends on the environmental and social characteristics of the region and is measured by the ability to anticipate, cope with, resist, and recover from drought.

Vulnerability considerations

Indicator	Vulnerability	
	High	Low
Rainfall	High variation	Low variation
Rate of change	Sudden	Gradual
Duration	Longer	Shorter
Food sources	Single	Multiple
Reliability on input from outside for food production	High	Low
Relation to other disasters	High likelihood	Low likelihood
Preparedness	Passive	Advance Warning
Leadership on mitigation	Insensitive	Sensitive

Vulnerable areas

Areas susceptible to the effects of droughts are those that have the following characteristics:

- High rainfall variability
- High land use intensity
- High population density
- Mostly high degrees of sloping agricultural land
- Type of crops grown are not suited to long dry spells
- Where only one or two staple food crops are grown
- Very high altitude (also affected by frosts)
- Heavily dependent on agriculture (as is the case for most of the population)
- No or limited diversity of the cropping systems (non-adoption of irrigation)

Areas of PNG which are expected to be affected meteorologically by the coming predicted drought (June 2002 to December 2003) include those in the following locations:

- Sepik plains
- Flat plains of Western Province
- Gazelle Peninsula
- Highlands (also frosts)
- Papuan South Coasts (Kwikila – Kerema)
- Milne Bay Province

Drought Analysis

We have used software developed by the Queensland Centre for Climate Applications to analyse the probability of droughts occurring in PNG. According to the 'International Rainman' program, which uses correlations with the SOI and the Pacific SST to analyse droughts, two types are usually referred to. Severe droughts are those experienced in years when rainfall received during a 6-months period is less than in the driest 5 per cent of calendar years, while moderate droughts are those in years when rainfall received during a 6-month period is less than in the driest 10 per cent of calendar years. Table 1 shows some weather stations in PNG, which have demonstrated good correlation between SOI phases (or values) and drought occurrence.

Figure 2 is a recently developed map showing drought vulnerable areas in PNG using four criteria only. The criteria are: number of staples cultivated, intensity of land use, garden slope and variability in rainfall. The ranks used are 1–4 for land use and rainfall variability and 1-5 for staples and garden slope. The highest rank (4 or 5) indicates high vulnerability and lowest rank (1) being low vulnerability. Table 2 shows the ranks used to determine vulnerability classes.

Table 1. Locations in PNG with good SOI correlations that, according to the International Rainman Program, experienced severe droughts and rainfall deficiencies during the period between 1957 and 1980

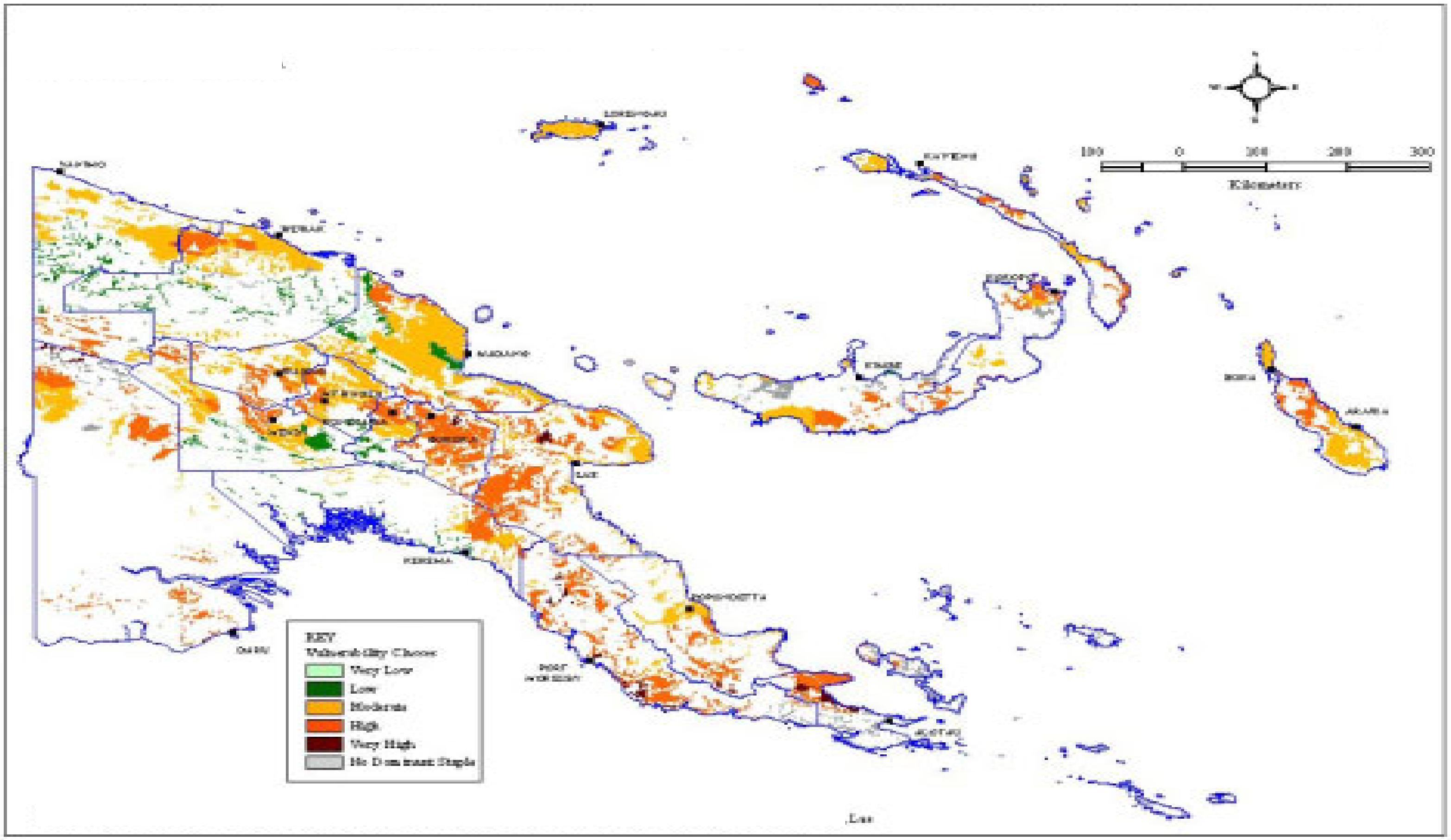
Location	Drought occurrence	Average Rainfall (mm) in drought years.	SOI Phase or Value (Average)
BEREINA DAL STATION	6	175	-1.9
KWIKILA	4	180	-3.0
DOGURA	4	248	-5.1
DARU A/F	6	283	-2.1
ITIKINUMU ESTATE	4	478	-9.6
BAIUNE UPPER (2)	5	558	1.2
GOROKA AERADIO A/F	6	570	2.7
WEWAK WO	3	582	-9.7
SAMARAI (COMPOSITE)	7	589	-2.5
KOITAKI PLTN (MF3)	6	603	-6.7
RABAUL WO	3	607	13.8
ILOLO PLTN SOGERI	4	635	-4.7
MENDI A/F	1	660	-12.7
MISIMA AIRPORT	6	668	-5.3
MADANG DASF	3	699	-5.9
KAVIENG WO	2	789	2.6
GARAINA TEA PROJECT	5	807	-4.5
KEREMA	5	895	-2.6
MOMOTE	7	1,086	5.3
LAKE KUTUBU	3	1,185	-10.2
KOKODA (YODDA)	5	1,213	-6.0
LOSUIA	1	1,380	4.9
KOKODA SDO II	8	1,418	1.5
LAE AIRPORT	5	1,582	3.7

Table 2. Data ranges used to determine the vulnerability classes

Summary Code	**Vulnerability Description**
5-6	Very Low
7-8	Low
9-10	Moderate
11-14	High
15-18	Very High

Most areas highlighted as moderate, high and very highly vulnerable to drought, were among the first to be affected in the current drought.

Figure 2. Drought vulnerable areas of Papua New Guinea (Using Agricultural System, Annual Rainfal and Coefficient of Variation to Rainfal)



Source: Map was produced using the Mapping Agriculture Systems Project (MASP) and the Climatic Tables of PNG, NARIHQ, Lae.

Study methods and analysis of impacts of the 1997 El Nino induced drought

Survey method

The major source of data was from information generated through, rapid rural appraisal. Family units in selected communities representing severely affected areas in the highlands and lowlands of Papua New Guinea were interviewed. Interviews were conducted using a questionnaire developed by the project. A total of 16 family units in each of the six districts were interviewed using the questionnaire, giving a total of 96 respondents.

Analysis of the impact of the 1997 El Nino induced drought

The main areas of the questionnaire included:

- Respondent's personal details
- Details of survey site
- General drought and frost impact
- Agricultural production
- Family income
- Water supply for household use
- Human health
- Alternative or famine foods
- Food aid/relief
- Migration
- Infrastructure and government services

Criteria for site selection

The six sites selected were considered vulnerable, based on the 1997 drought impact assessment survey report. The sites had been among the worst affected (category 4 and 5) in the country (Allen et al., 1997a and b). In order to get representative data, 2 sites selected shared a common altitude range. Furthermore, access to markets and the presence of infrastructure was assessed to determine if these impacted the ability of people to cope.

Elevations

Two communities were selected from each of the three altitudes

Altitude	Districts	Province
• 0-500masl	Raikos and Bogia	Madang
• 1501-2390masl	Bena and Gumine	Eastern Highlands and Simbu
• 2390 – 2620masl	Tambul and Kandep	Western Highlands and Enga

Types of sites or villages/communities

- A sample lowland site severely affected by drought with poor road infrastructure and limited market access- Raikos (Madang Province).
- A sample lowland site severely affected by drought but with good road infrastructure and access to markets- North Coast Road/ Bogia (Madang Province)

- A sample highlands site which was severely affected by drought but has good access to infrastructure and markets- Bena (EHP)
- A sample highlands site severely affected by drought with poor road infrastructure and limited access to markets- Gumine (Simbu)
- A sample highland site which was severely affected by frost but has good road infrastructure and access to markets- Tambul (WHP)
- A sample highlands site severely affected by frost with poor road infrastructure and limited market access- Kandep (Enga Province)

Table 3. Description of the districts surveyed

District	Altitude (m.a.s.l.)	Land use Intensity (R-Value)	Types of Staples	Road System	Market Access	Comments
North Coast (Bogia)	22 – 32	Low-Medium	Sweet potato, banana, cassava, taro, yam	Excellent sealed road	Good	-
Raikos	22 – 28	Low	Banana, cassava, sweet potato, taro, yam,	Main bridge has been washed out	Bad	-
Bena	1,525 - 1,584	Low-High	Sweet potato, cassava, banana,	Good	Fairly good	Distinct annual dry season (June - Oct)
Gumine	1,675 - 2,390	Low-Medium	Sweet potato, cassava	Not good	Not so good	Steep garden slopes
Tambul	2,388 - 2,624	Medium – High	Sweet potato	Good	Fairly Good	Frosts also experienced
Kandep	1,768 - 2,400	High	Sweet potato	Not good	Not so good	Frosts also experienced

Source: Survey data.

The R- Value is as follows;

$$\text{R Value} = \frac{\text{Cropping Period x 100}}{\text{Cropping Period + Long Fallow Period}}$$

KEY: 1-27 = Low, 28-50=Medium and 51-100 = High

The targeted group of people in these village communities were family units of subsistence farmers, ideally husband and wife together.

Profile of the study sites

The six vulnerable areas selected for the study are in the low and highlands of the country. The sites for drought assessments were Raikos, Bogia ,Bena and Gumine Districts The two sites selected to also assess frost risks were Tambul and Kandep, both high altitude areas.

Table 4. The strength, weakness, opportunities and risk management capacity of the 6 sites

Area	Strength	Weakness	Opportunity	Risk Management Capacity	Remarks
Madang North Coast (lowlands)	Good sealed road Reliable well water. Coconut and fish as back up. Betelnut sales provides income.		Access to wage employment.	High	High level of education / literacy
Madang Raikos (lowlands)	Coconut and fish as back up food	Road is not operational (bridge washed out)		Low-moderate	Access to market and services is a problem.
Eastern Highlands (Bena)	Road access is fairly good		Access to some wage employment	Moderate – High	It has a distinct dry season. People have adapted.
Simbu Highlands (Gumine)		Road access is often bad. Sweet potato and cassava are only staples.		Low	Garden on steep slopes.
Western Highlands (Tambul)	Good market for vegetables in Mt Hagen.	Crops affected by frost. Sweet potato is only staple.	To introduce frost tolerant starch crops.	Low	Vegetables are main cash crop.
Enga Highlands (Kandep)		Crops affected by frost. Sweet potato is only staple. Vegetable market is not accessible.	To introduce frost tolerant starch crops Introduce new cash crop (s) or revitalize the fledging pyrethrum industry.	Low	Wheat has been introduced as a food and cash crop. Traditionally, people have migrated during the droughts (frosts).

Source: Complied from survey data.

Assessment of farm performance during drought

Crop yields declined by up to 80 per cent in the 1997 drought year (Allen et al., 1997). The CGPRT Survey revealed farm yield was significantly reduced for all crop types. The crop types assessed were staples, vegetables, fruits, cash crops and perennial crops.

Assessment of coping strategies and preparedness of affected communities and local institutions (risk management and avoidance)

For the purpose of the workshop, data on income sources, domestic water supply, methods of plant material preservation, famine foods eaten and migration will be presented. A total of 92 families were recorded. The comparisons presented are between the 3 groups according to altitude ranges. The groups are Bogia/Raikos, Bena/Gumine and Tambul/Kandep.

Analysis of income sourcing

Table 5. The main income sources during the drought

Source	District: Bena /Gumine (29)		Bogia /Raikos (32)		Tambul /Kandep (31)		Total (92)	
	Respondents	%	Respondents	%	Respondents	%	Respondents	%
Food crops	23	79	22	69	26	84	71	77
Cash crops	23	79	29	91	7	22	59	64
Livestock	22	76	18	56	23	74	63	68
Assets	1	3	0	0	0	0	1	1
Savings	4	14	2	6	1	3	7	8
Royalties[1]	1	3	1	3	0	0	2	2
Betel nut	1	3	15	49	4	13	20	22
Fresh fish	0	0	15	49	0	0	15	16
Other	2	7	5	16	3	9	10	11

Note: Some mentioned more than one source of income.
[1] Royalties are payments made to resource or land-owners by developers of logging and mining projects.
Source: Survey data.

The bulk of the respondents, at all 3 altitudes, earned money from the sale of food, cash crops and livestock. Savings and royalty payments were used as well. The sale of betelnut in Bogia/Raikos in Madang was important for 49 per cent of the respondents there and provided for 13 per cent of the high altitude (Tambul/Kandep) respondents.

Coping with domestic water requirements

Table 6. Methods of obtaining household water during the drought

Methods	District: Bena /Gumine (29)		Bogia /Raikos (32)		Tambul /Kandep (31)		Total (92)	
	Respondents	%	Respondents	%	Respondents	%	Respondents	%
Settle near streams and rivers	2	6	1	3	0	0	3	3
Carted water	21	72	16	50	23	74	60	65
Bamboo piping	0	0	4	12	0	0	4	4
Wells	0	0	9	28	0	0	9	10
Coconut	0	0	10	31	0	0	10	11
Others	8	27	3	9	5	6	16	17

Note: The numbers of respondents who did not indicate any way of coping with the water shortage were: Bena/Gumine (5), Bogia/Raikos (9) and Tambul/Kandep (5).
Source: Survey data.

Three per cent of total respondents settled near rivers (Bogia/Raikos and Bena Gumine). Bamboo piping and wells were observed in Bogia and Raikos only and therefore, reduced carting was recorded. Respondents in the highland districts of Bena/Gumine and Tambul/Kandep mainly carted water from distant rivers. Coconut milk provided an invaluable source of drink in the 2 Madang districts.

Plant material preservation

It should be noted in Table 7, that the majority of respondents from high altitude areas (Tambul/Kandep) did not save seeds (presumably consumed), in contrast to the respondents from the mid altitude and lowlands, who did.

Table 7. Did you store planting materials during the drought and frost?

	District		
	Bena/Gumine (29)	Bogia/Raikos (32)	Tambul/Kandep (31)
Yes	20	31	8
No	9	1	22
Total	**29**	**32**	**30**

Note: The numbers in brackets show the numbers of people surveyed in each district. One respondent from Tambul/Kandep did not answer.
Source: Survey data.

Methods used to preserve planting materials for rehabilitation are shown in Table 8.

Table 8. Methods of storing planting material by district

Method	Bena/Gumine (29)	Bogia/Raikos (32)	Tambul/Kandep (31)
Store sun dried seeds	10	26	2
Dig ground and bury	2	6	0
Plant in swamp or marsh	5	14	0
Store seeds over fire place	15	23	6
Vegetative parts in water	2	10	0
Low lying areas	3	0	0
Others	0	5	0
Total	**37**	**84**	**8**

Note: Some used more than one method of storing material.
Source: Survey data.

The majority of respondents saved the seeds of annual crops. The respondents of Bogia/Raikos and Bena/Gumine also saved vegetative plant parts in water or swamp areas. The respondents of Tambul/Kandep did not save vegetative plant parts.

Famine foods

Table 9. Main bush/famine foods eaten during the drought

	Bena/Gumine (29)	Bogia/Raikos (32)	Tambul/Kandep (31)
Ficus	10	0	8
Ferns	16	1	10
Rungia	2	0	2
Wild taro	0	2	0
Tulip	0	19	0
Kumu mosong	3	13	0
Wild yam	6	26	0
Kang kong	0	2	0
Others	22	23	17

Note: The numbers of respondents who did not indicate any bush or famine foods were: Bena/Gumine (3), Bogia/Raikos (1) and Tambul/Kandep (7).
Source: Survey data.

Respondents of mid to high altitude districts consumed more bush vegetables (Ferns, Rungia and Ficus) than the lowlands people surveyed. Lowland respondents reported consumption of wild energy foods such as taro and yams as well as bush vegetables. The respondents from Bena/Gumine obtained some wild yam but those from Tambul/Kandep did not, as the plant does not grow at high altitude.

Migration

Table 10. Migration and destination

	District		
	Bena/Gumine (29)	Bogia/Raikos (32)	Tambul/Kandep (31)
Migrate out of area?			
Yes	3	5	12
No	26	27	19
Total	29	32	31
Where to?			
Lower altitude	1	0	8
Near a river	1	3	0
District HQ	1	1	6
Towns/villages	2	0	3
Other villages	3	2	5
Bush	0	4	0
Others	0	0	3

Note: Some respondents nominated more than one location they migrated to.
Source: Survey data.

There was more migration (39 per cent) of respondents at high altitudes (Tambul/Kandep) than those from the lower altitudes. Only 10 per cent and 16 per cent of respondents reported migration in Bena/Gumine and Bogia/Raikos respectively. Those who did, settled at lower altitudes, near towns or District Head Quarters or in other villages where food could be obtained. Those who migrated to towns sought jobs opportunities there.

Discussion

The survey showed that production of all crop types was reduced significantly during the drought. The coping strategies discussed here are income sources, plant materials, how domestic water was obtained, bush or famine foods eaten and migration.

The survey showed that of the 6 districts studied, dwellers of high altitude districts (Tambul/Kandep) are most at risk. This is due to the following reasons; the occurence of frosts, non-availability of energy foods in the wild and limited storage of planting materials for rehabilitation. No preservation of vegetative plant parts was mentioned, probably because frosts would kill them anyway. The post drought period can be a desperate time when people await the harvest of their crops.

This partly explains why a greater percentage (39 %) of respondents at Tambul and Kandep migrated. The people at high altitudes were prioritised to receive seeds and planting materials of crops distributed by AUSAID during post drought in 1997-98. Similar support has been given after past droughts.

The districts least at risk are Bogia and Raikos in the Madang Province. The respondents there have energy foods in the wild, have access to fish and coconut, access to betel nut for sale and are able to store both seeds and vegetative plant parts. In Bogia district, one village surveyed has a water well.

While the distinct dry season in Bena and sloping gardens in Gumine are serious vulnerability factors, the respondents there obtained wild yam and were able to store seeds and vegetative plant parts for recovery. Corms of banana (cultivars Kalapua and Yawa) were consumed as energy food in the Bena district.

The outlook for affected communities on future El Nino droughts

The people of the 6 districts surveyed have not had any significant positive changes in their socio-economic or agricultural systems in the past 5 years since 1977. There has not been any infrastructure development either. Therefore, it cannot be expected that they will better cope with future droughts. What the people can do is to adopt technologies into their production systems, which would improve their ability to feed themselves. These technologies are presented in the On-Farm Drought Contingency Plans developed by the National Agricultural Research Institute (NARI). The document is available upon request.

Since the Southern Oscillation Index (SOI) has been rapidly falling between April - June 2002 (-3.4 to -19.3), it would be wise for actions to be taken to prepare for a drought if and when it occurs. At least some form of preparedness would help minimize problems like those experienced during the 1997/98 drought that saw 40 per cent of the rural population (1.2 million people) starving.

Opportunities for managing droughts

Listed below are several opportunities available to PNG for managing droughts:

- Duration of droughts is usually short
- There is usually substantial rainfall even during dry years
- Diversity in genetic resources
- Availability of surface and sub-surface water resources
- Climate that is largely influenced by El Nino Southern Oscillation (ENSO)

The dependence on food aid is neither desirable nor sustainable; hence, coping strategies to manage drought are essential. The question to be asked now is whether it is possible to mitigate the impacts of droughts on food supplies in PNG.

Stages of a drought

A drought can be categorised into three stages:

Pre drought: Period from early warning to the appearance of adverse impacts on crop production

Mid drought: Period of complete crop failure

Post drought: Period from occurrence of drought breaking rains to first harvest

The following stages and indicators have been adopted for PNG.

Stages and Indicators

Pre-drought

Start: Forecast of dry conditions by weather bureaus

End: Crops start facing severe water deficits

Mid-drought

Start: Crops start facing severe water deficits

End: Return of good rains

Post-drought

Start: Return of good rains
End: Start of harvest of first sown/planted crop

On -farm contingency plans

There are 2 methods of agricultural drought mitigation. One is short term and the other is long term.

Short term

Once a drought has been predicted, contingency plans have to be grouped into the 3 stages in the vulnerable areas. Strategies need to be in place for preparing for the drought and for coping during and after the event. Technologies developed by the NARI World Bank Drought Response Project are also mentioned below.

Below are some activities recommended for each stage of the drought.

a) Pre-drought

- Advise planting drought tolerant crops (i.e. Kalapua and Yawa banana, cassava and sweet potato).
- Demonstrate and set up low cost water lifting devices both for crop irrigation and drinking.
- Demonstrate the usefulness of mulching in gardens.
- Advice on food processing and storage.
- Advice on saving extra plant materials, including seeds of annuals (vegetables).
- Advise population to save money and dry foods.
- Advise / publish indigenous coping strategies.
- Demonstrate in ground storage of tuber crops.
- Circulate information on control of sweet potato weevil (Cylas formicarius).
- Advise cultivation on swamp and wind protected (land pockets) areas.
- Provide information on bush/famine foods and preparation methods.
- Advice on production and storage of grains (maize and rice) and pulses (beans and peas).

b) Mid-drought

- Provide information on optimising harvests using scatter or sequential methods.
- Information on alternate (bush) foods and preparation methods.
- Boil water before drinking.
- Farmer maintenance of planting materials (in swamp and high, cool areas).
- DPI's, NPOs and Aid Organizations to multiply early maturing sweet potato varieties and vegetable seeds recommended by NARI.
- In ground storage of tuber crops.
- Control of sweet potato weevil.
- Provide information on the preparation of stored grains (maize) and pulses (bean and pea).

c) Post-drought

- Plant vegetable seeds (cucumber, maize and greens).
- Plant early maturing sweet potato.
- Rehabilitate rescued plant materials.

Long term (adaptive strategies)

These should be on-going technologies that farmers should adopt as El Nino risks become more common. Although, the adoption of the technologies would change the subsistence production system, they would improve the food security position of the farmers in vulnerable areas. These include:

- Cultivating suitable cassava varieties. Cassava is a drought tolerant crop.
- Cultivating suitable banana cultivars. Cultivars of Kalapua and Yawa banana are drought tolerant.
- Processing and storage of cassava.
- Production and storage of maize, peas and beans.
- Production and storage of rice.
- Installing simple irrigation systems.
- Install village water systems (gravity feed types) for back yard gardening.

The NARI World Bank Drought Response Project selected drought tolerant and early maturing varieties of sweet potato for lowland and highland farming systems. The project has also selected high yielding cassava varieties with low cyanide for both lowlands and highlands. Crop germ plasms at NARI research stations contain drought tolerant varieties of banana. Simple irrigation systems have been imported and tested under the project. A trial on mulching showed an increase in sweet potato yield.

NARI will start research on technologies for frost mitigation in 2003 under a project funded by the European Union.

Relevant national plans of action for future El Nino and drought

In PNG, the Director General of the National Disaster and Monitoring Office, based on advice from the National Weather Service, issues the warning of a drought. Following that, an Agricultural Drought Response Committee would implement short and long term On-Farm Contingency Plans developed by the National Agricultural Research Institute.

As part of the national strategy, rainfall monitoring would reveal which provinces or districts are most vulnerable and therefore, receive attention first. Agricultural Drought Mitigation would be administered through the Provincial Food Security Committees or the Provincial Disaster Committees. Activities would include workshopping contingency plans, demonstrating food processing and storage and irrigation systems.

Conclusion and recommendation

Conclusion

The study suggests that people from high altitude areas of PNG are more at risk during and after a drought, during which time frosts also occur. The natural endowments in these areas do not provide the requirements for inhabitants to sustain life when traditional food gardening is not possible. The lack of suitable agricultural technologies is another factor.

Recommendation

An ongoing implementation strategy of On-farm Contingency Plans with appropriate agricultural technologies in vulnerable areas is necessary as droughts (and frosts) become more frequent.

References

Allen, B.J. and Bourke, R.M, 1997a. Report of an Assessment of the Impacts of frost and Drought in Papua New Guinea, Port Moresby: Australian Agency for International Development.

Allen, B.J. and Bourke, R.M, 1998. The 1997 drought and frost in Papua New Guinea: overview and policy implications, Port Moresby: Australian Agency for International Development.

Allen, B.J. and Bourke, R.M, 2001. The 1997 drought and frost in Papua New Guinea: overview and policy implications. *In* R.M. Bourke, M.G. Allen and J.D., Salisbury (eds.), Food Security for Papua New Guinea. Proceedings of the Papua New Guinea Food and Nutrition 2000 Conference, PNG University of University, Lae, 26-30 June 2000. ACIAR Proceedings No. 99.

Allen, B.J. and Bourke, R.M, with Burton, J., Flew, S., Gaupu, B., Heai, S., Igua, P., Ivahupa, S., Kanua, M., Kokoa, P., Lillicrap, S., Ling, G., Lowe, M., Lutulele, R., Nongkas, A., Poienou, M., Risimeri, J., Shelton, R., Sowei, J., Ukegawa, K., Willson, N., Wissink, D and Woruba, M., 1997b. Report of an Assessment of the Impacts of Frost and Drought in Papua New Guinea –Phase 2, Port Moresby: Department of Provincial and Local Level Government.

INTERNATIONAL RAINMAN Program, 2001. Australia: Queensland Centre for Climate Application..

Maiha, S., 2002. Droughts in Papua New Guinea, Paper presented at NARI Drought Contingency Planning Workshop in June 2002, Lae, Papua New Guinea.

Rao, K.P.C., 2002. Planning for Drought Management, Paper presented at NARI Drought Contingency Planning Workshop in June 2002, Lae, PNG.

Comments on the Papua New Guinea Country Report: Stabilization of Upland Agriculture and Rural Development in El Nino Vulnerable Papua New Guinea

R.D. Ghodake[*]

Introduction

Papua New Guinea (PNG) experienced a severe and prolonged drought from March to November of 1997. The drought induced by El Nino was the worst of the 20th century. Crop yields were reduced by as much as 80 per cent in many areas, resulting in severe food and water shortages, human diseases, financial difficulties, and environmental degradation. Towards the end of 1997, about 40 per cent of the rural population (1.8 million people) suffered and starved. Upland agriculture was worst affected by the combined effects of the drought.

Almost 40 per cent of the geographical area of PNG is vulnerable to such droughts. These areas include most parts of the highlands[1], Sepik plains, flat plains of the Western Province, Gazelle Peninsula and pockets of Islands, Papuan South Coast and Milne Bay Province.

El Nino droughts are also frequent in PNG, which has experienced severe droughts in 1914, 1931, 1941, 1965, 1972, 1992 and the most recent in 1997/98, was the worst. There have been major El Nino events in 1877, 1888, 1899, 1905, 1923, 1925, 1930, 1940/41, 1957/58, 1965/66, 1972/73, 1982/83, 1986/87, 1991/92 and 1997/98.

All indications so far have confirmed (85 per cent probability) that another drought induced by EL Nino is in the offing and will result in mild to severe drought, beginning in mid 2002 and continuing until June/July 2003. Early signs of drought have been seen since late August 2002 in PNG, covering the Western Province Plains, Sepik Plain, Markham valley, Papuan Coast from Kwikila to Kerema, some parts of Milne Bay and widespread parts of the highlands.

Agriculture and rural development

It is pertinent to look at the importance of upland agriculture in rural development in the context of the project objective of stabilization of upland agriculture and rural development.

Almost eighty per cent of 5.3 million people in PNG live and eke out their livelihood in rural areas. They generally rely on agriculture and other natural resources for a living. Very little agriculture is irrigated and most of it is in upland areas. Rural development in PNG is directly dependent on positive changes in key rural sectors such as agriculture (including forestry and fisheries), commerce, industry and manufacturing, infrastructure and facilities, health, education, and law and order. However, agriculture, especially upland agriculture, is the

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[1] Areas of the high-altitude highlands are also affected by severe frosts.

mainstay of rural development in PNG. It has well established, but unrealised potential to assure food and nutritional security, generate income, reduce poverty, create balanced economic growth and achieve overall sustainable development. In the longer term, improvements in other rural sub-sectors must primarily come as a result of the development of the agricultural sector.

Therefore, sustained development of upland agriculture is viewed as the single most important strategy for mitigating the effects of droughts and frost and thereby effectively contributing to rural development.

The project

The involvement of PNG in the CGPRT research project, on the stabilization of upland agriculture and rural development in El Nino vulnerable countries, was timely. The project is expected to suggest ways to mitigate the damage caused by El Nino induced abnormal weather, drought in particular, on upland agriculture and to stabilize agricultural production and rural development in PNG. This happens to be a companion project with another research project on drought and frost response implemented by NARI with the sponsorship of the World Bank.

On the basis of surveys and research work undertaken by the National Agricultural Research Institute (NARI), Dr Sergie Bang – the National Expert from PNG – made his presentation covering:

- the findings from the phase 1 study and a detailed focus on phase 2;
- distinctions between El Nino induced droughts and normal droughts in PNG;
- 1997 El Nino impact on agricultural production including food supply, farm family income, water supply for irrigation and domestic use and human health;
- considerations to resource endowments, vulnerability, technologies, farming systems, management systems and income sources;
- the coping strategies and preparedness of various agro-eco-systems, resource endowments and communities, and arising implications;
- contingency and action plans during pre-drought, mid-drought and post-drought situations. Outline national and regional plans for mitigating the effects of future El Nino events and drought.

Policy frame and capacity building

In view of the importance of upland agriculture and the frequent occurrence of drought, it is imperative that the nation be equipped with appropriate policies and guiding frameworks, strategic contingency and implementation plans, institutional arrangements, co-ordinating networks, funding support, human resource capacity and monitoring and assessment mechanisms. These also must be comprehensive enough to address the social, economic and environmental effects of such droughts and their after-effects.

Long-term strategy for sustainability

With drought becoming more frequent and the impacts being long-term, there has to be a long-term strategy towards policy formulation and capacity building. These need to be based on systematic research and analysis, and must be institutionalized at various levels of governance and implementation. That will ensure the much-needed sustainability is ingrained in the systems and processes.

Institutional arrangement and responsibilities

At present, PNG has a number of organizations and agencies involved in coordinating and implementing disaster and emergency situations, including drought and frost. Such agencies include an apex body called the National Disaster Monitoring Office (NDMO), which reports to the National Executive Council, and takes lead in coordinating and monitoring relief efforts through the National Disaster Preparedness Committee.

In each of the 19 provinces, there is a Provincial Disaster Committee, which is activated, as and when needed. Standing committees on food security are established at the national and provincial levels. The Department of Provincial Affairs and Local Level Governments also assume the responsibility for the co-ordination of such emergency activities.

Besides, there are a number of national departments and agencies (such as the Department of Agriculture and Livestock and the Department of Health), provincial departments and a number of government and non-government agencies, community based organizations, church groups, and schools; who are involved in management and relief efforts. NARI is responsible for appropriate research, technologies, foundation material and training and advice. Also involved are a number of donor organizations such as AusAID, European Union, JICA and others who assist with financial and technical aid.

Currently, the above efforts are poorly coordinated and often create confusion and delays in reaching the affected people in time. Therefore, institutional arrangements and responsibilities need to be rationally organized and assigned through an appropriate policy framework, coordinating mechanisms, training and overall capacity building.

Forecasting, monitoring and assessment

Invariably, disasters and emergencies are difficult to predict and forecast. Recently, especially in the case of drought, there has been a number of models and prediction mechanisms that can be effectively used. Various national and international agencies are currently engaged in refining forecasting models and predictions. Some to name, are the International Research Institute for Climate Prediction (IRI), the National Climatic Prediction Centre (NCEP), the National Institute of Water and Atmosphere (NIWA), the Bureau of Meteorology (BMRC), the National Climate Centre (NCC), the Council of Scientific and Industrial Research Organisation (CSIRO), etc.

A strong correlation is found between the Southern Oscillation Index (SOI) and national weather data in PNG. The National Weather Service (NWS) in PNG uses this relationship for monitoring, predictions and warning on the basis of information available at a national and international level. This, however, requires interpretation and assessment in terms of its implications for agricultural production and food security. Research institutions such as NARI are now capable of deriving such implications and feeding these into appropriate coping, management and relief strategies. However, historical and cross sectional data is needed for location specific predictions and such data is currently lacking.

Also, an important aspect of drought management is its continuous monitoring so as to be able to upgrade information and advise the coordinating agencies and farming communities. Mapping of drought and frost vulnerable areas and degrees of drought impact are crucial for planning and delivering relief operations and are current possibilities through the mapping system abilities developed by NARI. This data and information also needs to be effectively used for impact assessment.

Most of the above activities are undertaken by various agencies and organizations purely on a voluntary and co-operative basis and are often loosely coordinated and managed. The monitoring aspect is regularly ignored during non-drought periods. There is very little coordinated planning or mandatory responsibilities. As we approach another drought, PNG certainly requires a systematic, organized effort to critically look at how best to place the responsibilities and accountabilities to individual organizations in improving the forecasting, monitoring and impact assessment.

Funding and resources

Although PNG is prone and exposed to a variety of disaster situations such as drought, earthquakes, tsunami, volcanic eruptions, pest and disease outbreaks in agriculture, human diseases, etc, there are no reserved or specially assigned funds to handle such situations. PNG has an annual planning and budgeting cycle and avenues of mining revenue. However, often donors and funding agencies are dependant on a first call, with very little in-house assurance mechanisms. Recent signs of EL Nino droughts in PNG were responded to by the National Disaster and Monitoring Office (NDMO) through their request to the National Government of Kina 10 million for funding support.

One obvious way appears to be creating a special trust account and fund that can be left to the care of responsible and accountable organization such as NDMO. Such funds can be apportioned through the current arrangement of the Finance Secretary's Advance and allocated on a priority basis to this special trust account. This will require appropriate policy changes, modified institutional arrangement and improved capacity and accountability.

Research and technology

It is often astonishing that PNG so severely affected, even by moderate droughts. The country being tropical, receives an average annual rainfall of 1500 mm, which is also fairly well distributed over the months of the year and areas of the country. Obviously the explanation lies in the agricultural systems and technologies, which are mainly root and tuber crop oriented and tree-crop based. Existing and indigenous practices only rarely focus on soil moisture and water management strategies and issues.

There is therefore, a tremendous scope for research interventions and appropriate technology development, which can look at drought resistant/tolerant crops and livestock species (including existing crops and the introduction of new crops such as cereals), improved soil-moisture and crop management practices, water/irrigation methods and drainage systems, integrated agricultural production and resource management systems, and improved climate predictions. The other area is post-harvest operations including storage, processing, packaging, transportation, marketing, and even ways of cooking and consumption.

NARI in PNG has made considerable progress in developing drought response technologies (crops, soil moisture management practices and climatic predictions) through a World Bank funded research project. However, this work requires continuation and further support to refine these technologies, look at newer options, and translate such results into drought management strategies through advice, training, material transfer, and co-ordinated implementation.

Risk management and coping strategies

Like any other risk, drought risk needs to be managed by employing risk aversion strategies, increasing risk diversification options, and improving risk-bearing abilities. These include diversification of crop and livestock activities, new technologies and cropping patterns, use of biodiversity, maintaining regional diversity, inter-regional trade and migration, general and crop insurance, credits and financial management, community based relief measures, employment guarantees and creation of capital assets, storage and processing, and community participation and sharing.

A number of indigenous drought coping and management strategies are practiced by farming and rural communities in PNG. These include use of various signs to forecast dry seasons and frost, garden practices to mitigate drought effects and to minimize frost damage, preservation of planting materials, managing water shortages for domestic use, famine and alternative foods, and socio-economic measures including migration. However, these are not fully satisfactory and are increasingly becoming forgotten as people and society move from traditional ways to a newer life-style of markets and marketing.

Contingency planning and implementation for pre, mid and post drought situations and delivery of inputs and services are other interventions that are crucial.

There is therefore, a clear need to preserve, support and encourage various risk management and coping strategies through appropriate documentation, research, awareness, and training through policy changes and capacity building at national, provincial and community levels.

Training and human resources development

The core and basic areas of capacity development are training, information sharing, and human resource development at all critical levels, such as policy planners, researchers, extensionists, coordinating agencies, input delivery and services, donors, farmers, community based organizations, and NGOs. This will require a long-term policy framework, funding and donor support, organizational ability, institutional capacity, research and technologies, appropriate communication and training methods, and human capacity. That will be the basic requirements for effectively mitigating climatic risks, alleviating poverty and sustainable rural development in PNG.

Coping Strategies against El Nino: the Case of Selected Communities in Talugtug, Nueva Ecija, the Philippines

Florentino C. Monsalud, Jaime G. Montesur and Rene L. Limosinero[*]

Introduction

The Philippines experiences drought at least once every five years and it causes tremendous havoc to the economy. During the 1997-1998 El Nino, losses to rice and corn alone amounted to more than US$ 240,000,000 (Librero *et al*., 1999). Under these circumstances the government reacted with a number of programs that are expected to address this problem. Among these include the Small Water Impounding Projects (SWIP).

Along with the introduced mitigation measures against the effects of El Nino are the strategies employed by farmers to cope with the impact of El Nino. Understanding the factors contributory to the effectiveness of these measures will be a useful guide to planners and policy makers.

Vulnerability of farmers to El Nino is dependent on the biophysical characteristics of their farm and on the socio-economic conditions of the community. The institutional support available to them is also critical in the level of preparedness in confronting the impact of El Nino.

Objectives

1) To determine the impacts of El Nino-related abnormal weather changes on agricultural production and farmers' income;
2) To document the existing farming systems, resources, infrastructure, institutions, and other socio-economic characteristics of selected El Nino vulnerable areas;
3) To determine the strategies employed by farmers and communities to cope with El Nino-induced agricultural risks; and
4) To draw up specific recommendations for the stabilization of upland agricultural production.

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Methodology

Selection of the study site

The criteria in the selection of the study site were the following: a) predominantly rainfed agricultural are; b) presence of the Small Water Impounding Project (SWIP); and c) the active involvement of the LGU.

Data collection

The study site was characterized with special focus on farming systems, agricultural resources, infrastructure, institutions, and basic socio-economic and biophysical characteristics. This information was gathered through the Participatory Rural Appraisal (PRA) that was conducted by a multi-disciplinary team. At the farmer level, data was collected through interviewing selected respondents representing the SWIP beneficiaries and non-beneficiaries (Table 1).

Table 1. Number of respondents per village

Village	Total Number of Respondents		
	SWIP Beneficiary	Non-SWIP Beneficiary	Total
Alula-Sampaloc	8	9	17
Buted	14	6	20
Maasin	14	8	22
Villa Boado	17	6	23
Total	53	29	82

Source: Survey data.

Results and discussion

The study site

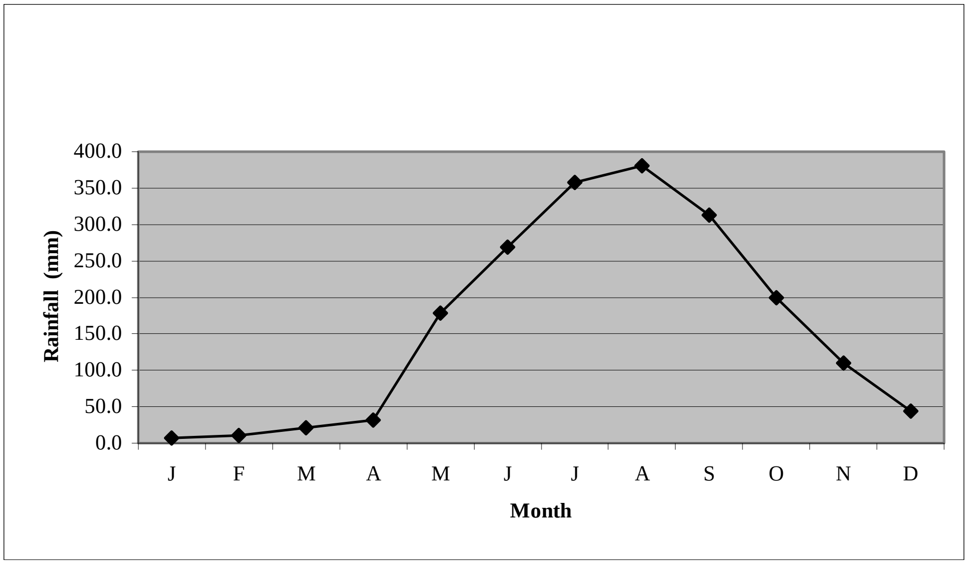
The study area was located in the Municipality of Talugtug, Nueva Ecija, the Philippines. It is situated in Central Luzon and about 180kilometers north of Manila. It covers a total land area of approximately 10,122 hectares and is divided administratively into 20 barangays (5 districts in the town proper and 23 agricultural villages).

The general topography of Talugtug is rolling to hilly in the northwestern and northeastern part. The western portion of the town is generally plain to gently sloping. About 75 per cent of the total rice production area of Talugtug is found here.

The climate in Talugtug is characterized by two distinct seasons, the wet and dry season. The wet months are form June to October while the dry period starts from Novermber and ends in May (Figure 1)

The dominant soils in the study area are Annam clay and clay loam, Maasin clay, Buted clay and Villa Boado clay (BSWM).

Figure 1. Rainfall distribution pattern



Source: OMA-Talugtug, 2002.

About 67 per cent of the land of Talugtug is devoted to agriculture while 22 per cent is pasture area (Table 2). The major portion of the cultivated agricultural area is cultivated to rice, about 6,704 ha. Other minor crops include root crops, corn and vegetables (Table 3).

Table 2. Land use of Talugtug, Nueva Ecija

Land Use	Area (ha)	Percentage
Agriculture	6,788	67
Pasture	2,257	22
Forest	618	6
Bodies of water	167	2
Built-up areas		
Residential	172	2
Institutional	21	0.2
Commercial/Industrial	0.92	0.01
Open Space	98	1.0
Total	10,122	100

Source: Survey data.

Table 3. Crops and area planted in Talugtug, Nueva Ecija

Crops	Land Area (ha)	Percent of Total Agricultural Area
Rice		
Irrigated	1,200	17.7
Rainfed	5,504.4	81.1
Vegetables	8	0.1
Corn	20	0.3
Rootcrops	56	
Total	6,788.4	100

Source: Survey data.

General characteristics of the selected villages

This study focused on agricultural communities which have been implementing the Small Water Impounding Project (SWIP). The four villages selected for this study include Alula-Sampaloc, Buted, Maasin and Villa Boado.

The selected sites are predominantly under rainfed agricultural production systems. The topography is generally rolling to hilly and small patches of flat to gently sloping. The total land area and dominant corps planted in the study area are shown in Table 4.

Table 4. Agricultural profile of selected villages in Talugtug, Nueva Ecija

Village	Land Area (ha)	Irrigated		Rainfed		Area Planted to:		
		Farmer	Area (ha)	Farmer	Area (ha)	Veg. (ha)	Cor (ha)	Root Crops (ha)
Alula	585.2	33	50	176	231	2	-	1
Buted	433.3	22	34	80	120	10	2	10
Maasin	470.8	143	165	85	130	-	-	-
Sampaloc	421.8	3	5	106	158	1	1	5
Villa Boado	233.2	20	30	80	120	5	-	2

Source: OMA-Talugtug Report 2002.

The age of the majority of the farmers in the study area ranges form 30 to 50 years old. The predominant size of the households in these villages is from 3 to 6. As to their educational attainment, the majority of the farmers have reached secondary level. The available labor force per household is generally low with only tow. The average landholding of the farmers in the four villages is about one hectare. The majority of the farmers have been farming for more than 10 years.

About 65 per cent of the respondents practice a rice-rice cropping pattern. Based on the rainfall pattern, the first crop of rice is planted in the months of June to July while the second crop is planted in November to December (Figure 2). Other cropping pattern practiced on a limited scale include: rice-fallow system, rice-vegetables, cassava-fallow, sweet potato-fallow, vegetables-fallow, fruit trees and banana. Animals that are raised in the study area are as follows: cattle, water buffalo, goat, swine, chickens and ducks. Water buffalo, cattle and goat are important components of the farming system in the area.

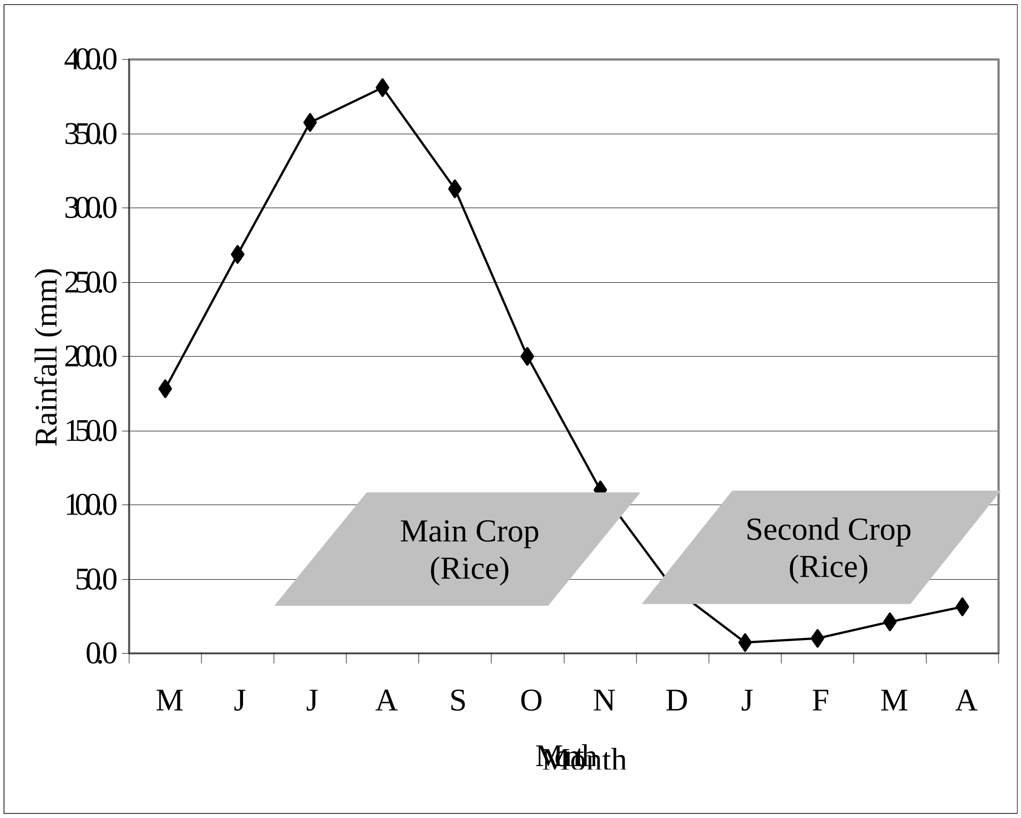
The SWIP's under study were established in 1993 (Sampaloc), 1995 (Buted), 1997 (Maasin) and 1999 (Villa Boado). A description of the SWIP's in the study area is presented in Table 5.

Table 5. Small Water Impounding Projects in Talugtug, Nueva Ecija

Location	Service Area (ha)		Watershed (ha)	Reservoir Area (ha)	Year Completed
	Wet season	Dry season			
Sampaloc	60	36	80	7.00	1993
Buted	60	32	70	7.84	1995
Maasin	100	60	218	22.64	1997
Villa Boado	60	36	75	6.19	2000

Source: Survey data.

Figure 2. Cropping calendar in the study area



Impacts of El Nino on rice yield and income

The effect of the 1997-1998 El Nino was experienced in the study. At the farm level, a significant reduction in rice yield and income was documented (Tables 6 and 7).

Table 6. Effect of El Nino on rice yield in Buted, Talugtug, Nueva Ecija

Water Supply	Cropping Pattern	Normal Climatic Condition Average Yield, kg/ha		Abnormal Climatic Condition (1997-1998) Yield, kg/ha	
		Main Crop	Second Crop	Main Crop	Second Crop
SWIP	R-R-F	3,500	4,750	3,500	5000
Rainfed	R-F	3,500	-	1,500	-

Source: Survey data.

Table 7. Effect of El Nino on net income per hectare of rice farm, Buted, Talugtug, Nueva Ecija

Water Supply	Normal Climatic Condition Net income/ha/year (US$)	Abnormal Climatic Condition (1997-1998) Net Income/ha/year (US$)
SWIP	736.82	808.18
Rainfed	312.59	8.08

Source: Survey data.

SWIP as a mitigating measure against El Nino

The benefits derived from SWIP, other than rice production, include extra income form fish production, recreational benefits, use to irrigate vegetables and forage production along the canal. The dam also serves as a drinking area for livestock. There are members of the community who use the water in the reservoir to perform household activities. Some farmers who are not direct beneficiaries of the SWIP also enjoy the same benefits, particularly on fist catch, forage crops and recreational benefits. As shown in Table 8, the harvester and the barangay where the SEIP is located have their share in the income generated from fish production.

Table 8. Income form fish (tilapia)

Village	Year	Harvester Share (US$)	Barangay Share (US$)	Irrigators Ass. Share (US$)	Landowner Share (US$)
Buted	1998	495.35	24.76	235.29	235.29
Maasin	2000	1,183.69	59.18	562.25	562.25
Villa Boado	2000	176.98	8.84	84.08	84.08

Sold at US$ 0.88 – 0.98 per kg.
Source: Survey data.

Benefits derived form SWIP

Farmer level
Increased productivity • Two cropping of rice made possible • Increase in yield per unit area • Growing of vegetables made possible • More kinds of plants/crops can be grown like onion, garlic, tomato, and other vegetables • Integration of fish in the rice production system • Integration of livestock made possible • Forage corps can grow vigorously • Dam is used as area for livestock to drink • Water in the reservoir is used in cleaning the animals Risk reduction – losses due to abnormal weather may be avoided. (El Nino also affects the first cropping; with SWIP however, success of the main crop is high).

Community level
1. Fish production made the following possible: • Availability of cheap fish • Some residents are allowed to fish if just form home consumption • Harvesters of fish receive a share of the produce • Additional income for the water users' association 2. Labor demand increased by the increase in cropping intensity and integration of fish culture. 3. Area becomes destination of some local tourists. 4. Many people from the community use the dam for swimming and washing clothes. 5. Spirit of cooperation put into practice. 6. New techniques in farming were provided by the LGU. 7. Five per cent of SWIP income goes to the barangay. 8. Construction of better roads. 9. Used as picnic area.

Municipal level
1. The presence of a SWIP in Talugtug was the main factor considered in choosing this municipality as a project site. 2. Development of a road network in the barangay was facilitated through the SWIP

The key informants indicated that the construction of better roads may not be directly implemented because of SWIP but considered it as one of the justification made for giving priority to the road improvement project. The local executive who was responsible for the road improvement was also very supportive of the SWIPs in the municipality. AT the Municipal level, they key information argued was that SWIP and activities related to it contributed in making their municipality known to other institution or donors and as a consequence other development project were introduced. The appreciation by the local government of the SEIP in a number of barangays within Talugtug, as perceived by the informants, somehow facilitated the development of the road network. The total support received and projects implemented in the municipality were linked to SEIP and hence, are considered benefits derived due to SWIP.

Consequences of SWIP Implementation

1. No need for farmers to go to other towns to work as rice harvesters.
2. Increased income.
3. Farmers are able to buy mini tractors and farm animals.
4. Additional income for the education of the children.
5. Improvement in the living conditions within the community.
6. Farmers are able to build concrete houses.
7. Farmers are able to by home appliances.
8. Better access roads provided.

SWIP is important not only because it gives assurance for the ability of water during the dry season but also contributes to making the farmers be able to mitigate the impact of El Nino. At the community level, it also offers a number of reasons why it is crucial to the lives of the people in the community.

Farmers' coping strategies

The farmers in the study area have their own strategies in coping with the impact of El Nino. Below are the major activities they have been employing:

1. Cogon (*Impirata cylindrical*) gathering.
2. Charcoal making.
3. Harvesting rice on other farms mostly outside the community or in other municipalities/provinces.
4. Working in construction and other non-farm jobs within and outside the community.

The effect of El Nino can be very serious to farmers who are not served by irrigation or a SWIP because of the following situation which are the results of crop failure:

1. More activity on charcoal making.
2. Migration which may result in neglecting agricultural activities.

Charcoal making affects the stability of the watershed. If the majority of farmer resort to cutting down trees for charcoal making, the situation may contribute to the further destruction of the watershed. Consequently, the problem of water availability is aggravated.

Migration impacts agricultural productivity because many of the farmers may find work outside their baranay or municipality more rewarding. Chances are, the farms will be attended to only when desired or when there is no longer any other alternative. This will consequently cause a lowering in the agricultural productivity and hence, food security could be affected.

Needs of farmers

The farmers have different perceived needs in their farming activities. Many expressed the need for capital which is intended for the purchase of farm inputs such as fertilizer, seeds, pesticides, field supplies and materials, It should be noted however, that the needs vary from the different villages considered.

Buted was the only site that did not express the need for capital. It instead focused on the need of the association to improve the canal by having it cemented. The other crop production related concern was on pest control.

The Sampaloc site also expressed concern for the canal to be cemented to minimize the loss of water along the earth canal. The need for capital form farm inputs and pumps was expressed at this site.

Appropriateness of SWIP

The appropriateness of SWIP as a mitigating measure against the effect of El Nino may be evaluated based on the farming system. In the study area, the main crop is rice and the design of SWIP was intended for this crop and possible diversification. The well-known addition is fish, through its introduction in the ponds. One should not forget that rice production is the farmer's primary objective; their intention is to use the water in the reservoir for rice production first before any other commodities, including fish. Therefore, in times of prolonged dry periods, major components of the faring system are affected.

It should be noted however, that changing the cropping system will always be faced with resistance on the side of the farmers. In terms of acceptance of the introduced technology, the introduction of BFS by the BSWM, it is apparent that many of the farmers are not yet ready to accept the technology at increasing productivity and decreasing the cost of fertilizer input (Table 10). Farmers are indicating a lack of capital in their production system but when the inputs are offered to them, still a number of farmers are hesitant to accept the technology. It

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Table 10. Acceptance to Balanced Fertilization Strategy (BFS)

Village	Target Number of Cooperators	No. Participated	Per cent Participation
Buted	15	7	47
Maasin	26	20	77

Source: Survey data.

What is appropriate, especially during El Nino, is the avoidance to plant rice on the second cropping. If this is not acceptable, then the association should make all efforts to make sure that the SWIP only operates to capacity.

If planting rice cannot be avoided then there must be some modifications made to the cropping calendar. This way the use of water can be maximized. Also, other water conservation measures should be introduced to farmers. If water conservation is not practiced, having the SWIP will not be enough.

Conclusion

The study documented that a SWIP can help farmers cope against El Nino. It is necessary however, that farmers should be ready to make adjustment in farming practices and accept other alternative strategies like water distribution schemes to avoid total crop failure.

References

FSSRI, 2000. Participatory Rural Appraisal Report: Maasin, Talugtug, Nueva Ecija.

FSSRI, 2000a. Participatory Rural Appraisal Report: Villa Boado, Talugtug, Nueva Ecija.

Librero A.R., F.C. Decena and A.B.C. Durana, 1999. Assessment of the Effects of El Nino in Phippine Agriculture, Los Baños, Laguna, the Philippines: PCARRD.

OMA-Talugtug, 2002. Report of the Office of the Minipal Agriculturist, Talugtug, Nueva Ecija.

Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, 2001. El Nino Southern Oscillation: Mitigating Measures. Los Baños, Laguna, the Philippines: PCARRD.

Talugtug Municipal Profile, 2001. Talugtug, Nueva Ecija.

Stabilization of Upland Agriculture and Rural Development in El Nino Vulnerable Countries: Thailand's Case

Thamrong Mekhora[*]

Introduction

Upland agricultural and El Nino effect in Thailand

Upland agriculture in Thailand relies mainly on rainfall and its distribution. Although the influence of the Southwest wind brings heavy rains or extremely wet weather throughout the country for six months during May to October every year, Thailand temporarily faces El Nino events. The impacts of El Nino in 1992 and 1997 especially, were significant. They were directly related to the decrease in the average amounts of rainfall in each region and over the main river basins, including the Chao Praya and the Mune-Shi river basin in the Northeast. These evidently caused a decline in yields of the major crops, including rice, maize, sorghum and sugar cane, especially in 1997.

It is forecast that El Nino will affect the region again in 2002 and 2003, as the abnormal weather approaches Thailand. As for the records from the Meteorological Department, the annual rainfall in Lop Buri and Nakhon Ratchasima dropped from 1,170.8 and 1,141.8 mm. per year of the three-year average of 1998 - 2000 to 890 and 880 mm in 2001, respectively (Figure 1). The temperature also increased significantly (Figure 2). Even though the amount of rain was still enough for upland crop production, in practice some losses may have occurred. The loss to major crops may also affect the socio-economic situation of the people in the vulnerable areas. These effects will be collected and explained in the following chapters. Moreover, it is certain that these people have vast experiences of drought and their existing measures to mitigate the losses may be proposed. Finally, measures and mechanisms to cope with the El Nino phenomenon are investigated at the farm level.

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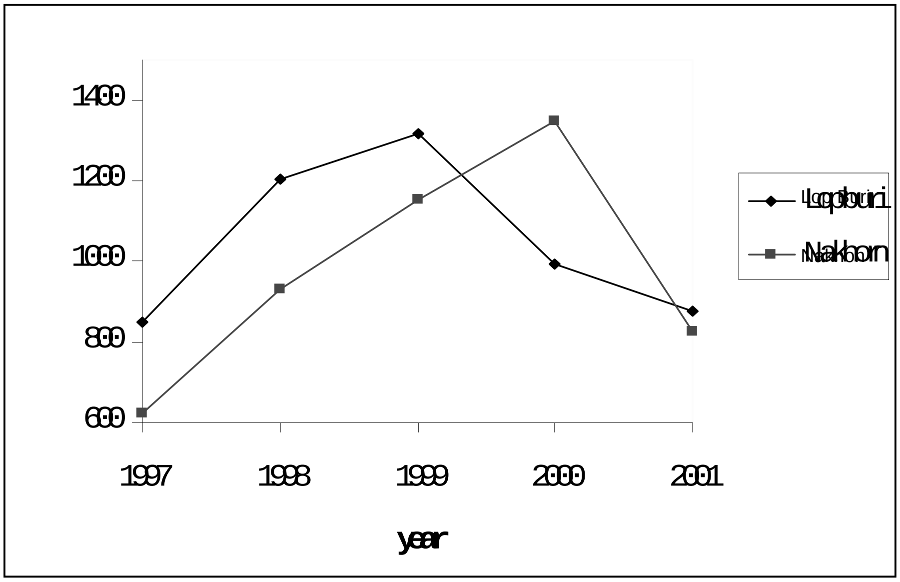
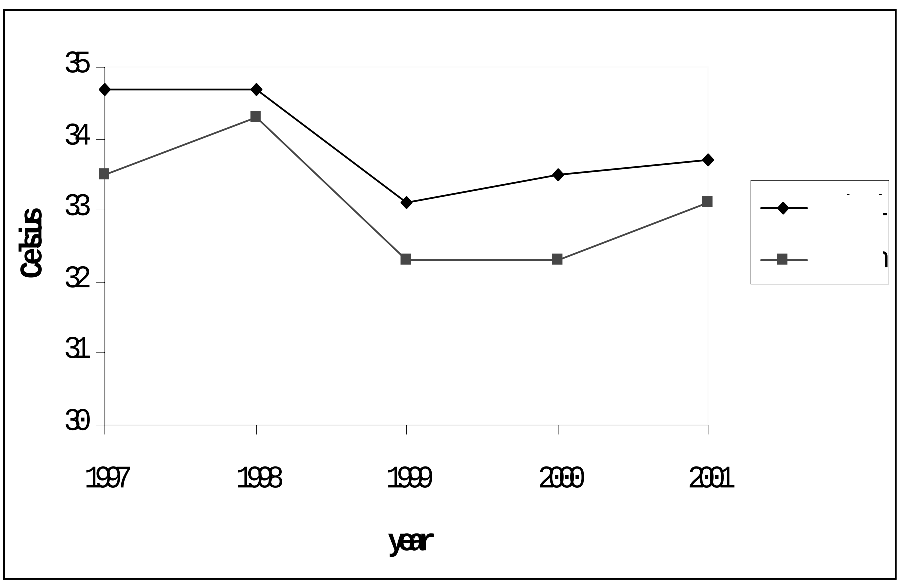
Figure 1. Annual rainfall (mm.) in Lop Buri and Nakhon Ratchasima, 1997 - 2001



Source: Meteorological Department.

Figure 2 Average maximum temperature (Celsius) in Lop Buri and Nakhon Ratchasima, 1997 - 2001



Source: Meteorological Department.

Literature review

Suwanabatr and Mekhora (2002) revealed that the El Nino phenomenon may affect harvested areas and yield of considered crops in Thailand. In 1997, these impacts, in terms of agricultural production and social and economic conditions, occurred clearly in some parts of the upland regions in the Northeast and Central plain areas where most of the CGPRT crops were planted. The impacts on the environment and natural resources were a severe drought and a long period of water shortages. Labour mobilisation, buying power and loan repayments were also impacted. However, the Thai government has continuously implemented measures and mechanisms and encouraged local initiatives to deal with abnormal weather effects. Existing effective counter measures are rain-making, reforestation, seed subsidies, crop diversification and agricultural restructuring and well-planned irrigation management.

Suwanabatr and Mekhora (2002), however, have not yet been able to reveal how far the impacts of abnormal weather affect the farmer's household. Moreover, what measures are carried out by farmers to overcome their problems and how far the government goes in handling the El Nino problem. Finally, what are effective measures at the farm level. This study will focus on these details.

Scope of the study

Evidence of abnormal weather occurred in 2001 when the rain was less than the previous years and the high temperatures were from January to March 2002. The rain came early in May 2002. Thus, the period of 2001 is suitable for the study.

The objectives of the study are to analyze and evaluate El Nino impacts at a farm-household level and farmer's responses and government measures to overcome the El Nino problems. These objectives are broken down into:

(a) To collect and analyze data and information of El Nino impacts on production, income, labour allocation and food security at a household level.
(b) To evaluate farmer's strategies in coping with the El Nino problem, constraints faced by farmers and the support requirement.
(c) To evaluate government strategy in handling the El Nino problem which includes concepts, approach and its implication in fields.

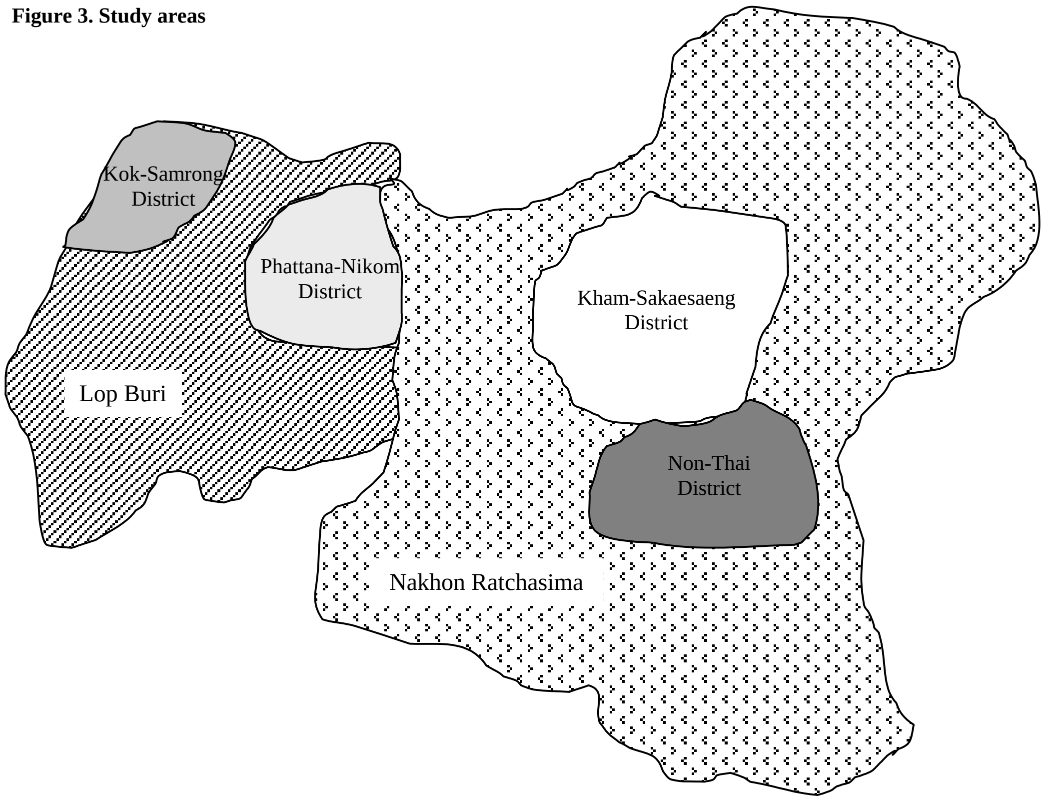
This research will be conducted in two different communities where effects of El Nino were experienced in 2001. The emphasis of this study is on production, cropping systems, household characteristics, farmer's attitude toward measures and mechanisms to solve the problems and food security at household and community levels.

Data material and research methodology

The study area

Figure 3 indicates that the areas for this study are in two diverse provincial regions. Lop Buri located in Central Thailand and Nakhon Ratchasima in the Northeast. Each province covers two sample districts where upland crops dominate. There is a large variety of upland cropping patterns in these two provinces. Both are major upland areas in Thailand. Lop Buri was once named as the corn belt of Thailand while Nakhon Ratchasima was the cassava plantation area. Lop Buri is much more productive due to the high quality of its soil, but water is hard due to the limestone rock base. Nakhon Ratchasima, on the other hand, is less productive because of the sandy soil and ground water is salty due to the salty rock base.

Figure 3. Study areas



Data collection

Choice of data collection methodology is a major aspect of achieving the objectives of the study. The wide spectrum of farm characteristics, measures to cope with the drought problem, cropping patterns of the upland areas and the nature of the envisaged analyses to achieve the objectives, precluded the use of only one particular data collection method. Thus, several methods were adopted and used for collecting the data required to satisfy the study objectives.

The major proportion of data used in this study was collected as primary data regarding household members and their movements, measures to deal with drought problems and different aspects of the small farmer cropping system. Both formal and informal surveys were employed. In addition, supplementary secondary data was used where available. This included rainfall data, village socio-economic information and government policies and measures to address drought conditions.

Sampling techniques

It would have been desirable, as a first stage in sampling, to use theoretical formulation to obtain the size of sample on the basis of major indices to be studied and relate these to the costs of obtaining information. Lacking prior knowledge of these indices, however, made this impossible. Thus, more practical methods under the small farmer environment of the study area were preferred. Consequently multi-stage cluster sampling techniques were adopted.

The basic administrative areas in Thailand's province were considered to be a cluster. Each province included districts. The first stage of sampling was to select two upland dominated districts in each province. The second stage of the sampling technique was to randomly select five villages from each of the districts. Each village contains approximately 100 farm-families. The final stage of sampling involved the selection of 12 farm-families from the selected villages. The 240 households were selected mainly on a subjective basis. The criteria for selection are outlined below:

- rainfed agricultural practice;
- five years experience in upland crop production;
- accessibility of the farmers;
- farmers' resourcefulness.

240 farm-households were used in the major analysis reported in this study.

Questionnaires for primary data collection

In the case where formal surveys were used, several precoded questionnaires were developed. The precoded questionnaires were preferred because they saved on both time and space; and the use of computer analysis had been envisaged. Also, prior knowledge of the farms characteristics and the existing farming system was used in the construction of the questionnaires. Open questions were included to obtain the information otherwise not specifically accounted for in the pre-coding. Field acreage, yields, costs, incomes, family members and cropping patterns are examples of this type of question.

Information on risk attitudes of the farmers was obtained through both formal and informal surveys. These included discussions between the author and the respondents, the measurements of yield loss and the observation of constraints experienced by the farmers due to their natural environment.

Field problems and limitations

Conducting a study of small farm agriculture with the objective of collecting farm characteristics, management data on cropping systems and drought and attitudes towards government policy and measures, there are several problems to be overcome. Some of the problems are briefly discussed with an illustration of how they were solved. This was an attempt to improve on the general accuracy of the data used. The problems were experienced both in the field and during data analysis and interpretation.

(a) Enumerators: Although they were trained prior to being sent into the study areas, enumerators faced unexpected findings during the survey. Some observations were not available during the daytime and the interview had to take place in the evening. Tiredness may cause a reduction in the quality of the interview. Moreover, an appointment was made and used to be certain that the required samples were obtained. This caused an increase in the cost of data collection.

(b) Farmers: The farmer's problems varied from skepticism to unavailability. They did not keep any records about their past or planned activities. Information regarding past events could only be acquired through "memory recall". Reliability of this information is questionable since accurate memory recall is greatly reduced when the investigated events are of continuous variability. To circumvent this problem, direct observation and measurements of events by the enumerators were preferred where feasible.

Skepticism arose mainly from past experiences with other data collectors that had made unfulfilled promises. Therefore, while sympathizing with such farmers, efforts were made to establish beneficial support and no promises were made.

(c) Physical: Some small farmers used traditional quantity measures of inputs and outputs based on local measurements. Although the local units were accepted during the survey, official weight scale measures were carried out. All volume measures were converted to a common metric ton weight measure during data compilation.

Production function analysis

Model specification

The production function is a mathematical way of describing the relationship between the production of a given input and the factors affecting the production process. The production function is based on the SEAM of the Multiple Regression Analysis (MRA). The MRA is an extension of the Ordinary Least Squares Simple Regression Model (OLSSRM). The OLSSRM is extended to include more than one explanatory variable. Thus the MRA indicates the technical relationships between the outputs and the various factor inputs in the production process of the different cropping patterns. The changes in the dependent variable can be explained by reference to change in several other independent variables. The model can, therefore, be used for the estimation of statistical parameters, hypothesis testing and prediction. The underlying model assumptions and consequences of their violations are in standard econometric textbooks.

Effective measures and policy to mitigate El Nino effects

Introduction

This chapter will present the information of villagers in terms of farm-family structure, household size, farm size and land use. Also, the details of villagers' experiences about abnormal weather will be investigated. Moreover, the analysis is concerned with the investigation of drought effects in the year 2001. Starting from the perception of villagers for government warnings, the measures to mitigate the effects are evaluated, including water preparation for drinking and other domestic uses, production planning, rice storing and others. Effective measures from the past are monitored, and the required help from the government is established. Farming practices concerning environmental soundness are observed.

Farm-family structure

Considering family structure, the establishment of sex composition and distribution is required. The number of housewives per household may also be emphasized. The sex composition and distribution is important since labour availability and distribution of farm activities are divided among sexes. Agricultural production on a household basis in rural areas is divided among sexes too. Generally, males perform strenuous tasks, such as soil preparation and transportation, while females accomplish those tasks requiring more dexterity, like seeding and weeding.

The average number of males per household ranged from 2.02 in Nakhon Ratchasima to 2.32 in Lop Buri. For females, the numbers per household ranged from 2.08 in Nakhon Ratchasima to 2.10 in Lop Buri. When compared to 1996, the number of males in Lop Buri remained the same, while the number of females increased. On the other hand, the number of males in Nakhon Ratchasima in 2001 decreased from 1996, while the number of females increased.

The change in the numbers of males and females from 1996 to 2001 was not significant when taking the abnormal weather into consideration. Some moved in and out due to social reasons, such as weddings, family movement or finding permanent work off of the farms.

The male/female ratio in terms of average sex distribution per farm-family is almost one to one. Sex distribution, however, shows a preponderance of females in Nakhon Ratchasima in 2001. In Lop Buri, there is a higher male proportion.

Household sizes

In this study, household size indicates the number of persons living wholly or partly together, sharing the same facility in the house and eating from one pot. This literally implies those persons who constitute a household and are supported from the same fields.

In 2001, the average household size sampled, ranged from 4.1 persons in Nakhon Ratchasima to 4.42 persons in Lop Buri. Low quantities of the coefficients of variation imply that variations in the family sizes between two provinces are relative stable. Structural Thai culture dictates one household has one wife and one husband. Moreover, the impact of birth control has led to some families only having one or two kids.

The farm size in Lop Buri, 74.68 rai, was twice as large as that in Nakhon Ratchaburi, 37.62 rai. The farm size in 2001 also increased slightly from 1996 in both provinces. Upland rainfed rice dominated the cultivation area in Nakhon Rachasima, while maize dominated the planting area in Lop Buri. The crops in Lop Buri were more diversified than in Nakhon Ratchasima. The cash crops included mungbean, groundnut, cassava, sugar cane, sesame and chili. Trees and fruit trees were also planted by small numbers of villagers. Some fruit trees were difficult to adapt to upland areas. Animals were also raised on some farms. Cattle, milk cows and poultry were found around the study areas. Fish were rarely bred due to the difficulty in storing water in fish ponds.

The change in farm size from 1996 to 2001 was due to land rent from neighbors, while most villagers had the same farm size. This indicates that the effects of the drought in 1997 did not cause the loss of farm size or planted area in the study areas. The villagers were still living in their villages and cultivated their land as normal. One important characteristic of Thai people is endurance. After having settled, they will live on their land forever. Movement occurs when they are forced to move out of their place rather than volunteer.

Villagers' experiences concerning El Nino effects in year 2001

This study selected the year 2001 as representative of an abnormal year because the rain was less than the normal and the temperature was also higher (figure 1 and 2). Furthermore, the Thai government had launched a campaign to warn people countrywide about abnormal weather approaching Thailand. There were many sources of media being used, such as radio and television broadcasting, newspaper and government services. This section focuses on the response of villagers to that warning and their preparation to deal with the drought effects.

(1) El Nino and abnormal weather warning.
When asked about the news of El Nino and abnormal weather (drought), the majority of the respondents in both provinces had received that information.

(2) Production plan after warning.
For the respondents who had received the warning news, 51 per cent in Lop Buri made the adjustment of their production plan while only 35 per cent in Nakhon Ratchasima did the same. This information indicates that the villagers in Lop Buri were able to revise their production plan better than the ones in Nakhon Ratchasima.

(3) Water for drinking and domestic use preparation.
After receiving the warning, only 29 per cent of the informed villagers in Lop Buri prepared water for drinking and using, while 80 per cent of the ones in Nakhon Ratchasima did. Since the villagers in both areas are living in upland areas where water is not sufficient for use the whole year round, all have been purchasing big jars for storing rain water for drinking for decades. The initial cost of construction was 2,400 baht in Lop Buri and 3,000 baht in Nakhon Ratchasima. In areas where the ground water table is not so deep and the water quality is good for consumption, government agencies constructed shallow tube wells to supply water to the villagers. The alert of villagers in Nakhron Ratchasima may be due to the saline ground water.

(4) Additional income.
When the abnormal weather approache, 50 per cent of the respondents in Lop Buri sought additional income to compensate the loss of their produce, while 62 per cent in Nakhon Ratchasima did. This implies that abnormal weather may affect the villagers' income in both provinces, but in Nakhon Ratchasima it was stronger than in Lop Buri.

(5) Rice storing preparation for household consumption.
After receiving the information of abnormal weather in 2001, only 26.3 per cent of villagers in Lop Buri stocked rice for family consumption while 65 per cent of villagers in Nakhon Ratchasima did. The low percentage in Lop Buri was due to the insignificant effects of drought in the past and high options to find additional income to compensate the loss from abnormal weather. Compared to Lop Buri, villagers in Nakhon Ratchasima were really aware of the hazardous effects of the drought. Rice barns are traditionally established within households in the upland areas. The villagers will keep their rice until the new product has already been harvested and make certain that their family members will have enough rice for the coming year.

(6) Temporary movement.
The effects of drought may force the villagers in upland areas to move out of the village to find new jobs or additional income. The survey found that the majority of the villagers in Lop Buri still lived in their villages while some of the villagers in Nakhon Ratchasima temporarily moved out.

(7) New career.
The effects of abnormal weather in 1997 and 2001 forced some household members to find new careers out of the villages. 20 per cent of villagers in Lop Buri informed that their members had taken permanent careers outside of agriculture. Forty per cent of villagers in Nakhon Ratchasima had their family members find permanent jobs elsewhere.
One effect of the drought in 2001 was a failure in production which led to an increase in the debt of the households. The survey found that the debt of the majority of villagers in both provinces increased. The comparison also indicated that this problem was stronger in Lop Buri than in Nakhon Ratchasima. This may be due to the high value of the loans that they borrowed from the bank.

(8) Loan payment.
When the debts increased, loan payments might also follow. The survey found that although the majority was able to pay back the loan as normal, 46 per cent of villagers in Lop Buri were indebt.

(9) Government measures to relieve the El Nino effects.
In practice, when abnormal weather occurs, the government services will survey the loss and the required help of the villagers and then report to the central government with mitigating measures. The central government will annually allocate some of its budget for this purpose, including flooding and other natural disasters. Among the

proposed measures, the effective ones are seed provision, village funds and food supply distribution. Budget transfers to develop water measures are as follows:

(9.1) **Seed provision** This measure is proposed when drought destroys the crop after having been planted. Almost 60 per cent of observations in both provinces accepted that the seed provision measure was very useful. Just above 20 per cent of villagers, however, rejected it because they had experienced delay in its delivery and its quality was not sufficient.

(9.2) **Village fund establishment** This transfer policy was implemented in 2001 with the villagers' self operation. The government deposits the one-million-bath fund for villages and city communities through the Bank of Agriculture and Agricultural Cooperatives and the Governmental Savings Bank. The villagers set the members, committee and regulation for using and the return of the loan. They have to maintain and increase the fund forever.

Most of villagers in both provinces accepted that the village fund was very useful (80 per cent in Lop Buri and 76.7 per cent in Nakhon Ratchasima) and useful (16.7 per cent in Lop Buri and 20 per cent in Nakhon Ratchasima). Only a few of the respondents did not agree with this measure. The advantages of the village fund are the low interest rates determined by the villagers and the villagers' decision how to make use of their loans.

From observing the villages, some village fund members used the loan to establish small-scale rice mills in the village, the others borrowed it and formed a team looking for construction work in cities. Other activities included diversifying traditional crops to livestock and poultry and even household consumption.

(9.3) **Food supply distribution** Sometimes drought may cause the failure of food production and also cash crops which earn cash to buy food, therefore, the government may supply food to relieve this problem. This measure is very useful and useful to more than 61 per cent of villagers in both provinces.

(9.4) **Water resource development** This measure is the most important to solve the effect of drought. More than 90 per cent of respondents in both provinces would like the government to allocate budget to villages and develop water resources. The water for household consumption that has been developed, included ground water and a plumber. For agricultural purposes, weir construction and small reservoirs are examples of water development. Although the demand for water development is very high, sites for construction are limited.

Expected help from organizations when drought is approaching

When drought is approaching its concerned effects are the failure in agricultural production and income loss, the difficulty in supplying food and water for drinking and using, and struggling to survive in the villages. Apart from their own self-sufficiency, groups of people and organizations are historically expected to help households solve the problem. This issue is addressed when interviewing the community leader with how the groups of people and organizations help when abnormal weather occurs, a high level of support, moderate or none. The answers were then transformed into the acceptant scores, with their interpretation of 1 – 1.49 being none, 1.50 – 1.99 being moderate to none, 2.00 – 2.49 being moderate to high, and 2.5 – 3.00 being high. The results are as follows:

(1) **Village leader** This person is selected by the villagers and works as a messenger to report the evidence from villages to the government agencies and vice-versa. This

study found that the attitude of households towards the village head scored moderately to none.

(2) **Monk** The temple and monk is the holistic place centered in each village. Some village activities are performed well under the monk's management but their assistance did not cover the problems of drought. Therefore, the attitude score was low but it meant very little.

(3) **School** The school and teachers are the center of education in each village. However, when drought is approaching, the households did not expect the help from this organization. The attitude score was also very low.

(4) **Tambon Council** Tambon is a subdivision of a district and comprises of villages. Tambon council's are formulated by villagers' votes and established as a local organization to use a transfer budget from the central government for local development. Contrary to the expectations of the author, the attitude score was low

(5) **Regional agricultural extension officer** The Department of Agricultural Extension locates its structure and offices in provinces and districts. Each district office has its personnel who are responsible for transferring agricultural technology to farmers, collecting information of disaster and crop failure by pest and disease and recording the annual agricultural statistics of crop and animal production for planning in each tambon, namely 'kaset tambon'. These officers work very closely to households. They not only report the evidence to the central government to allocate budget and materials to alleviate loss, but also distribute them to the households. Therefore, they received the second highest score among the groups and organizations from the households when help is requested to solve drought effects.

(6) **Public health officers** The Ministry of Public Health has also established their local offices in each tambon. Drought may cause problems to villagers' health. However, overall, a health care facility is not required by the people in the study areas when drought is approaching. The households' attitude toward this issue scored low.

(7) **Community officer** The Ministry of Interior localized the community development office in each district. The rural household and development community is under its responsibility. Most work is to organize the village fund and off-farm activities. The attitude of households toward community officers was low, meaning that they did not provide any help concerning the drought problem.

(8) **District governor** The Ministry of Interior also localized the district governor to look after and service the people in each district. Community order, calamity, peace and happiness under law and government policy are its responsibilities. The attitude of households toward community officers was also low.

(9) **Provincial governor** The provincial governor is a representative of the central government to administrate all government services in the province to provide activities to the villages. The attitude of households toward community officers was low.

(10) **Central Government** The present government won election in 2000 and have launched new projects and programs to develop both rural and urban areas. The well-known projects include the delaying loan payback project, one million baht village fund, thirty baht for medical care and one village one product. These projects are effective and satisfy the demand of the villagers. Therefore, they expected that when abnormal weather occurs, the central government was able to solve their problems.

Measures and support requested by villagers when drought occurs

Each household was asked to respond, if drought occurred, what kinds of measures and support they requested from the government? Three measures ranked openly. For the first measure, 37.5 per cent of the total households requested water resource development, 23.3 per cent required seed subsidy and 16.7 per cent wanted the establishment of a village fund which provides low interest rates to the villagers.

For the second measure, a village fund was requested by the majority of the households (35.8 per cent). Seed subsidy, water resource development and price intervention measures followed and counted for 24 per cent, 17.2 per cent and 14.7 per cent respectively. Villagers in both provinces responded similarly for price intervention and other measures. The differences occurred in the case of a village fund and water resource development measures (Lop Buri required more) and seed subsidies (Nakhon Ratchasima required more).

For the third measure, a village fund was still the most popular measure, counting for 29.5 per cent. Price intervention, water resource development and seed subsidy followed and counted for 19.1 per cent, 18.2 per cent and 11.8 per cent respectively.

It can be concluded that when drought approaches, the effective measures requested by villagers are those of water resource development, a village fund, seed subsidy and price intervention. These measures have been implemented. However, water resource development, such as reservoirs and dams is limited due to the characteristics of upland areas. The village fund is very popular since the government transferred the budget to establish one million baht in each village in 2001. Both seed subsidy and price intervention were occasionally implemented.

Farm practices concerning environmental issues

Most upland crops grown in Thailand, a tropical country, are prone to attack by many kinds of insects. Chemical utilization is normally adopted as the fast and effective method to control pests and diseases. However, the uses of chemicals may lead to environmental harm and insecticide resistance of pests. Alternative methods to control the pests and the practice of using chemicals were investigated in the study areas. Included, are insect counting before using chemicals, physical insect control, biological insect control, bio-chemical insecticides and integrated farming systems. The survey found details as follows:

(1) **Insect counting before using chemicals** Chemical utilization is normally to overdose due to a lack of knowledge of farmers and the outbreaks of pests and diseases. The practice of insect counting before using chemicals has been proposed by the agricultural extension person to use chemicals wisely and safely for a decade. However, the study found that only 20 per cent of households practiced this method and the number of respondents in Nakhon Ratchasima was higher than the ones in Lop Buri.

(2) **Physical insect control** This method is cleanliness but requires intensive labour. This study found that only 3.8 per cent of households in Nakhon Ratchasima used this method, while none of the households in Lop Buri used it.

(3) **Bio-insecticide** Some plants and tree leaves are able to be extracted to produce bio-insecticides, such as neem trees. With simple tools and techniques, farmers themselves can produce bio-chemicals and use them for insect control. The survey found that only 6 per cent of households used bio-insecticides while the majority did not. Both provinces had a small proportion of households that used bio-chemicals.

(4) **Residual ploughing** After having harvested the crops, some farmers ploughed their residuals back into the soil, accounting for 26.7 per cent. The number of respondents

that used this method in Lop Buri (36.7 per cent) is higher than in Nakhon Ratchasima (16.4 per cent).

(5) **Manure utilisation** Most farms (62 per cent) in Lop Buri used manure for soil improvement while some (34 per cent) in Nakhon Ratchsima did.

(6) **Crop rotation** Most farms (68 per cent) in Lop Buri rotated their crop annually while very few of farms (0.9 per cent) in Nakhon Ratchsima did.

(7) **Mixed farm system** Most farms in both provinces (92 per cent in Lop Buri and 89 per cent in Nakhon Ratchasima) mixed one crop with others.

Production function analysis

Model specification and assumptions

Specifying multiple regression equations for productivity estimates, uses production function analysis. The regression equations are based on the Single Equation Approach Model (SEAM) where the production functions for the different cropping patterns were considered as single independent relationships between the dependent variable and the explanatory variables (factor inputs). The production functions as individual functions were, therefore, assumed not to be influenced by other relationships relevant to the economic milieu enveloping the production process.

Model specification in the statistical analysis involves the specification of production functions for the different cropping patterns. The technical relationships between the outputs of the various cropping patterns are weighted in monetary units and the various factor inputs in production are determined. Monetary unit weighting is preferred in accounting for the preponderance of different physical units found between and within the cropping patterns. The production surface for different cropping patterns is portrayed by their different lead regression equations. The degree and direction of influence of the factor inputs on the outputs with consequent implications are also noted. This is important in directing policies towards government and farmer levels. Other than the conventional assumptions underlying the Multiple Regression Model, land, labour, seeds, fertilizers and variable costs of chemicals were assumed to be important explanatory variables and included in the implicit function. The postulated relationship between the dependent and explanatory variables for the different cropping patterns is implicitly expressed as follows:

y = f(x1, x2, x3, x4, D, u), where
y = value outputs of the cropping patterns in baht;
x1 = farm sizes of the cropping pattern in rai;
x2 = labour inputs for the cropping pattern in ME-days;
x3 = seed inputs for the cropping pattern in kg;
x4 = chemical fertilizers for the cropping pattern in kg;
x5 = variable costs of chemicals for the cropping pattern in baht;
D = dummy variable, 1 = Lop Buri, 0 = Nakhon Ratchasima;
u = stochastic random error term covering both unquantifiable and omitted explanatory variables from the function.

From the relationship of the implicit function, it is implied that the variables in the value of the outputs of the copping patterns are explained by variations in the explanatory variables. However, since for any production process, there are unquantifiable and omitted explanatory variables, the relationship is not exact – hence the inclusion of a stochastic error term in the model.

The production function can further be explicitly expressed for convenient regression equation form, fitted to the data as follows:

$$\log(y) = \log b_0 + b_1\log(x_1) + b_2\log(x_2) + b_3\log(x_3) + b_4\log(x_4) + b_5\log(x_5) + D$$

where: b_1 = constant or intercept, indicating output of the cropping pattern when there is no organized production;

$b_1, \ldots b_5$ = regression coefficients for the equations; and

log = natural log linear or linearised Cobb-Douglas.

Correlation among variables

The interpretation of the partial correlation coefficients is closely connected to the multiple regression model (MRM). For the MRM, correlation might exist between any two variables included in the function. The degree of correlation is examined through the partial correlation coefficients. These measure the correlation between any two variables, when all other variables are held constant, that is, when the influence of other variables has been removed. Where the degree of correlation is between only two variables, it is a simple correlation. The simple correlation between any two variables x_1 and x_2 (Rx_1x_2) can be defined by a correlation coefficient as:

$$R_{X1X2} = \frac{\Sigma x_1 x_2}{\sqrt{\Sigma x_1}^2 \sqrt{\Sigma x_2}^2}$$

The correlation coefficient only assumes values from –1 to +1. Where $Rx_1x_2 > 0$, the variables increase or decrease together. If $Rx_1x_2 = +1$, then there is perfect positive correlation between the variables. If $Rx_1x_2 < 0$, the variables x_1 and x_2 move in the opposite direction and when $Rx_1x_2 = 0$, the two variables are uncorrelated.

The partial correlation coefficients derived between the variables included in the production function analysis for the different cropping patterns were positive in all cases, although varying from one cropping pattern to another. Most variables are most highly correlated to the value of output, except the chemical cost in the case of rainfed rice, cassava and maize. Further examination of the correlation matrices among unexplained variables reveals a high correlation between farm size and some variable inputs as expected. In all cases, farm size had high correlation with labour and seed. This included its high correlation with chemical costs in the cases of sugar cane and maize-sorghum cropping patterns. However, the correlation between the chemical costs and other selected inputs was relatively low. A high correlation between any two explanatory variables usually causes concern because of the possibility of multi-collinearity. In this study, however, there are some major problems of multi-collinearity of farm size since collinearity statistics of explanatory variables prevail high tolerance values and low VIF.

Empirical results

Prior to reporting the results of the multiple regression model, it was essential to identify the most suitable mathematical equation of the production function that could best fit the data. The appropriate equations were selected on the basis of the following criteria:

(1) Ease of mathematical manipulation and economic interpretation of the production parameters;
(2) “Goodness of fit” using the magnitude of the CMD, R^2;
(3) The significance of the overall production function as judged by the F-values;

(4) The appropriateness of the signs of the regression coefficients within the range of the observations and the production logic; and

(5) The significance of the t-values of the regression coefficients.

Cobb-Douglas was selected since it meets the first criterion. Moreover, it is open to mathematical manipulation and economic interpretation of the production parameters. Considering rainfed rice, the coefficients of multiple determination (R^2) for the fitted equation were 0.83. This then implied that the explanatory variables explained 83 per cent of the variability in the output value. The remaining proportion of the variability in the output can, therefore, be attributed to the variability in the stochastic error term (u). The latter, accounts for the omitted explanatory variables and such erratic variables as climatic effects, pests and disease incidence and specific soil quality conditions that are normally not easy to quantify.

For the cassava, sugar cane, maize, maize-sunflower and maize-sorghum cropping patterns, the CMD (R^2) were 0.81, 0.86, 0.85, 0.76 and 0.82 respectively. Consequently the explanatory variables explained approximately 81 per cent, 86 per cent, 85 per cent, 76 per cent and 82 per cent of the variability in the output of cassava, sugar cane, maize, maize-sunflower and maize-sorghum respectively.

Economic interpretation

Production elasticities

Production elasticities can be considered as elasticities of response with respect to different explanatory variables. They indicate a percentage change in output resulting from a relative percentage change in input. The coefficient indicating individual input elasticity can be calculated as the product of the marginal physical product of a given input and the reciprocal of the average product of that input. The production elasticity can also be obtained as direct regression coefficients of the log-linear function.

The production elasticity, indicating a percentage change in the outputs of the different cropping patterns relative to a percentage change in the individual outputs, showed that there are several explanatory variables. The sum of their elasticities of response, indicating the effect of a similar change in all the inputs together, gives the economies of scale of production. The scale of production, also known as the ‘scale coefficient’, indicates the returns to scale which are considered under three categories, according to the magnitude of the coefficients. If the sum of the production elasticities is greater than 1 ($\sum E_p > 1$), there are increasing returns; if it is less than 1 ($\sum E_p < 1$), there are decreasing returns; and if the sum is equal to 1 ($\sum E_p = 1$), there are constant returns to scale. When there are either constant or increasing returns to scale and the prices of both inputs and outputs remain constant, there is no economic optimum level of production.

Table 1. Production elasticities by cropping pattern

	Production Elasticities					
Cropping pattern	Land	Seed	Fertilizer	Chemical	Labour	Returns to scale
Upland rainfed rice	-0.347	0.153	0.260	-0.002	1.071	1.135
Cassava	1.106	0.100	0.028	0.027	-0.572	0.689
Sugar cane	0.743	-0.034	0.294	0.066	-0.119	0.950
Maize	-0.468	-0.497	0.236	-0.006	2.146	1.411
Maize-sunflower	0.043	0.097	0.386	0.139	0.342	1.007
Maize-sorghum	1.111	-0.318	0.082	0.776	-0.517	1.134

Source: Author’s calculation.

Further discussion of the production elasticities in this section, are based on the Cobb-Douglas function. For the maize-sunflower cropping pattern, for example, the production elasticities of the individual explanatory variables are less than one and positive. Thus, if each of the inputs is increased by 1 per cent, the output of this cropping pattern will increase but be less than 1 per cent. Hence, marginal production becomes smaller as the level of any individual input increases, while others are held at a geometric mean resulting in diminishing returns. Where diminishing returns occur and the elasticities of production for each of the inputs remain positive, production will, on average, be maintained in the economic range at the stage II level. However, when elasticity of production is greater than 1, as is in the case of land in cassava and maize-sorghum cropping patterns and labour in the cases of rice and maize, the increasing marginal product is greater than the average product. If the other resources are kept constant, only more uses of land and labour can increase the output and the level of this output is in stage I (and irrational stage) of production.

The negative elasticities of production occurred in various inputs in most cropping patterns. Included are, farm size in the cases of upland rainfed rice and maize, labour in the cases of cassava, sugar cane and maize-sorghum, seed in the cases of sugar cane, maize and maize-sorghum, and chemicals in the cases of rice and maize. The negative elasticities imply that use of more of these inputs would reduce the outputs of the various cropping patterns. This is a result of the negative marginal productivity of these inputs being at the level of stage III production.

The summation of the production elasticities of the various explanatory variables gives a measure of the returns to scale. There are increasing returns to scale for rice, maize and maize-sorghum. Consequently, an increase in profits for these cropping patterns, where returns to scale are increasing, can be achieved if outputs are expanded through varying all the inputs together and keeping both factor and input prices constant. For cassava and sugar cane, the returns to scale have a coefficient of less than 1. Therefore, decreasing returns to scale prevail. This indicates a situation of economic optimum, however, certain important factors of production might be omitted, such as soil and labour quality. For the maize-sunflower cropping pattern, the sum of production elasticities accruing to individual explanatory variables is equal to one. Therefore, this cropping pattern exhibits constant returns to scale. A point of economic optimum is attained since the marginal product and average product are equal here and the latter is at a maximum, marking the start of the rational stage of production.

Marginal Productivity Value (MPV)

Judging from the level of technology and availability of price of both inputs and outputs, marginal value productivities can be used as a measure of the resource use efficiency in a given production process. Maximum efficiency of a resource use is attained when the MPV is equal to the cost of input. In such a situation an economic optimum occurs. The MPV are the value terms of the marginal physical products and are derived as the products of the marginal physical outputs and the output price.

The marginal productivity values are attained as the direct regression coefficients of the linear equations for the different cropping patterns. The table below indicates the marginal productivity values with respect to the variable inputs in the production function analyses for the different cropping patterns.

Table 2. Marginal productivity value by cropping pattern

Cropping pattern	Marginal productivity value				
	Land	Seed	Fertilizer	Chemical	Labour
Upland rainfed rice	-495.79	18.99	15.74	-0.51	126.62
Cassava	1,721.78	0.43	-7.27	6.31	-56.45
Sugar cane	1,798.39	1.86	40.52	-0.04	55.18
Maize	-256.24	-334.08	14.57	0.14	406.61
Maize-sunflower	331.56	6.63	13.81	5.78	144.52
Maize-sorghum	2,731.28	226.24	0.76	26.83	-240.32

Source: Author's calculation.

The MPV of land for cassava, sugar cane, maize-sunflower and maize-sorghum cropping patterns were highest in comparison to those of either labour or variable inputs. This means that land plays a major role in explaining the variation in outputs of these cropping patterns. Moreover, land could be brought under cultivation. However, the capacity to expand acreage was limited, the MPV of land may be useful as a proxy to indicate an estimate of the potential rental values attached to each cropping pattern.

In the case of labour, the MPV for maize and rice were highest in comparison to those of either land or variable inputs. This reflects the efficient use of labour and its generally high productivity. The MPV of labour were slighly lower than those of land in the case of sugar cane and maize-sunflower cropping patterns. Therefore, labour was the second proportion of major importance in these cropping patterns.

The MPV of variable inputs of seed, fertilizer and chemicals were very low in comparison to those of land and labour, except for the case of seed in a maize-sorghum cropping pattern. This again indicates an inefficient use of planting material due to the effects of abnormal weather.

The MPV of land were, however, negative for rice and maize cropping patterns, and of labour for cassava and maize-sorghum cropping patterns. Expansion of acreage and labour in these cases could, therefore, lead to decreased outputs.

Effects of drought on major crop yield in 2001

Abnormal weather affected Thailand in 2001, although it was not as strong as the one in 1997. Less rain occurred in the study areas and regional records reveal that the rainfall was less than the three-year average of 1998 - 2000. It is certain that the rainfall factor will physically influence the efficiency and ability to produce the upland crops under the ceteris paribus assumption. The method applied for this measure is elasticities, which are frequently used for convenience to express the demand and supply response to price. The elasticity (E_p) shows the percentage change in one variable associated with the percentage change in another variable and hence, is independent of the units of measurement. The calculation of rainfall effect on yield simply expressed as the percentage change in yield over the percentage change in rainfall.

Table 3. Elasticity of rainfall reduction to crop yield

Major crops	E_p	Std.
Rice	1.66	0.63
Maize	1.19	0.43
Sunflower	0.94	0.30
Sorghum	0.74	0.22
Cassava	0.67	0.17
Sugar cane	0.41	0.12

Source: Author's calculation.

From Table 3 above, among the considered crops, less than average rainfall in 2001 affected rice the most, followed by maize. Compared to other crops, the limited rainfall affected sugar cane the least, followed by cassava.

Summary and recommendations

Summary of findings

The objectives of this study are to investigate the effects of El Nino at the farm level and to evaluate the measures to mitigate those effects in upland areas of Thailand. Two representative provinces in the Central plain, namely Lop Buri, and Northeast plateau, namely Nakhon Ratchasima, are used. One hundred and twenty samples in each province were randomly selected from the study areas. The survey was conducted in early 2002 and the data was based on crop year 2001/02.

The survey found that the farm family in both provinces was rather small. The average size was four and the family labourers were two. These numbers were not different from 1996. The average farm size in Lop Buri, 74 ria, was twice as large as the farm size in Nakhon Ratchasima, 37 rai and both slightly increased from 1996. There were various crops and trees grown in the study areas. However, upland rainfed rice, cassava, sugar cane and maize, dominated. There were also cattle, milk cows and buffalo raised widely in the study areas.

Upland area villagers in both provinces had long experience with rice and water shortages. All households had had big jars, used to store rainwater for drinking, for decades. Where groundwater is suitable, the government implemented shallow well construction for household consumption. There were also some weirs, small reservoirs and water plumbers in the study areas. For rice storage, some households in Lop Buri had a building for this purpose, while most villagers in Nakhron Ratchasima had. The paddy would be traditionally kept in rice storage buildings until the new harvesting season was coming. This is to make certain that the household members have enough rice for consumption the whole year round.

The Thai government always pays attention to abnormal weather. Radio, television broadcasting and its regional agencies were the media utilized for this purpose. The campaign was conducted in 2001 and villagers in both provinces received this warning. The results were adjusting their production plan, water preparation, rice storage, and additional income searching. The effects of drought were losses in crop yields and earnings, and an increase in dept and difficulty to repay loans. Seed provision, a village fund, water resource development and food supply distribution were effective measures that satisfied the need of villagers. When drought was approaching, persons and organizations to help mitigate its effects were the central government, regional extension officers and the village leader. The most preferred measures were those of seed provision, water resource development, village fund establishment and price intervention.

The next study was to investigate farm practice concerning environmental issues. The study found that most farms had experience in the use of manure, diversified crops and crop rotation. Only a few of them used the method of counting the number of insects before using chemicals, bio-chemicals, physical insect control and residual ploughing

The application of production analysis revealed that sugar and sugar cane cropping patterns had decreasing returns to scale. The increase of all inputs together, may lead to a decrease in output. Upland rainfed rice, maize and maize-sorghum cropping patterns revealed increasing returns to scale, the increase of all inputs together may lead to increase in output. The maize-sunflower cropping pattern was the only pattern that revealed constant returns to scale and economic efficiency. Under the situation of abnormal weather, land and labour were among the inputs that use efficiency in a given production process. The decrease in rainfall from the normal years of 1997 - 2000 to 2001 led to the decrease in crop yields. Rice and maize yields were affected the most, while sugar cane and cassava the least.

Recommendations

(1) Water for drinking and household consumption: The evidence indicates that most villagers have the facilities already and enough water for drinking and household consumption. Moreover, the government has paid attention to water resource development continuously and determined it as a first priority for the country development policy. Therefore this issue is not of interest.

(2) Water for agriculture: Since both study areas are located in the upland areas, it is difficult to construct reservoirs. Rain is the only water supply source, therefore, rainmaking is the best way to increase the amount of water when a drought is approaching.

(3) Food security: Since Thailand is a food surplus country and most farms in the study areas are self-sufficient in rice, food security measures are not necessary to be implemented. However, one of the most practical policies is to expand the rice mortgage project to cover the upland areas where the villagers have stored their paddy in their barns and require some money with a low interest loan.

(4) Cropping systems: Most farms have experience in switching crops from normal ones to ones with a smaller water requirement. Kenaf is to replace rice, chili and sugar cane to replace maize, sunflower and sorghum to replace second season maize. Trees and fruit trees are less important to both study areas. If trees did bring moisture to the environment, the suggestion should encourage farmers to grow them. Some land should be allocated to grazing land for cattle and cows.

(5) Drought warning system: The warning system is very effective to warn people and help them prepare and adjust their activities before the loss comes. Now, the media in terms of television and radio is widespread throughout the country. The government should utilize this facility as much as possible.

(6) Crops resistant to abnormal weather and some varieties of traditional crops should be researched and introduced to replace the ones with a high water requirement. However, these projects were implemented in the past but failed because there was not a market for the new crop. Therefore, both technical and economic (market) feasibility should be considered.

Reference

Suwanabatr, B. and Mekhora, T., 2002. Stabilization of Upland Agriculture under El Nino-induced Climatic Risk: Impact Assessment and Mitigation Measures in Thailand. Working Paper No. 63, Bogor, Indonesia: CGPRT Centre.

Comments on the Thailand Country Report

Wirat Krasachat[*]

Review on first phase study

The El Nino phenomenon might affect agricultural production in terms of a decrease in harvested areas and yields of considered crops in Thailand. The impacts on the environment and natural resources were indicated by the experience of broadly severe drought and a long period of water shortage. The impacts on social and economic conditions were indicated in terms of labour mobilization and a weakened degree of buying and loan repayment abilities. Existing effective measures have been rainmaking, reforestation, seed subsidies, crop diversification and well-planned irrigation management.

The first phase study has not yet investigated the impacts of abnormal weather on farmer's households and what mitigating measures the farmers and the government used effectively at the farm level. Thus, the second phase study focuses on the above issues.

Comments on second phase study

The scope and objectives of this study were well defined. The study area and data collection were carefully considered. Survey problems and limitations were pointed out and socio-economic information on farmers was also included. Villagers' experiences concerning El Nino effects in 2001 were investigated. Government measures to relieve the El Nino effects as well as expected and requested support for the villagers, when drought approached, from institutes were also investigated.

To my knowledge, the effects of drought on major crop yields in 2001 were first quantified in this study.

A few areas should be improved or considered carefully:

Firstly, model specification and assumptions. Due to the limitation of resources (such as labour, land, finance, etc.) and agricultural household decisions, SUR (Seeming Unrelated Regression model) should be considered to compare the results with SEAM (Single Equation Approach) for each crop. If the Cobb-Douglas production function is used, constant returns to scale should be imposed due to its assumption.

Secondly, the effect of El Nino on farm income and its distribution (if possible) should be included in the study.

Finally, due to the valuable information at farm level obtained in this study and the author's experience on policy implementation in Thai agriculture, a few issues should be considered. Most government agricultural policies have focused on land productivity improvement and price intervention. This study should pay attention to market-oriented policy which has rarely been considered to date.

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Whatever policy is to be formulated, it should be a long-term plan, not an occasional plan or help. The policy should also target poverty alleviation and rural development. I personally would like to encourage the author to do better in the areas of policy formulation.

Appendix 1: Program of the Joint Workshop

Joint Workshop

Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific

17-19 September 2002
Cebu Plaza Hotel, Cebu City, the Philippines

Co-organized by
ESCAP CGPRT Centre, Department of Agriculture, Philippines, Japan International Research Center of Agricultural Sciences (JIRCAS), Australian Centre for International Agricultural Research (ACIAR), International Water Management Institute (IWMI)

Tuesday 17 September 2002

8:30 Registration
9:30 Opening Program — Moderator: Jaja Siena (BSWM)
Invocation
Philippines National Anthem

Welcome remarks
Director Eduardo B. Leciones, Jr.
Department of Agriculture-Region 7

Opening messages
Hon. Pablo P. Garcia
Governor, Cebu Province

Hon. Ernesto M. Ordonez
Undersecretary, Department of Agriculture, Philippines

Mr. Arcadio Cruz
Program Officer, FAO

Mr. Eiji Ueno
First Secretary (Agriculture), Japanese Embassy, Manila

Dr. Takahiro Inoue, President, JIRCAS
(to be read by Mr. Tomohide Sugino, JIRCAS)

Dr. Nobuyoshi Maeno
Director, CGPRT Centre

10:30 Break

11:15 **Rationale, objectives and benefits of the joint workshop**
Dr. Rogelio N. Concepcion, Director, BSWM, Philippines and
Regional Advisor, ELNINO Project

12:00 Lunch

13:00 **Keynote Presentations** Moderator: Mr. Kiran Pyakuryal (Chief, RDS, UN-ESCAP)

Assessing the effects and impacts of climate variability on water availability and formulating adaptation and mitigation strategies
Dr. Felino P. Lansigan, International Water Management Institute (IWMI)

14:00 **Seasonal climate forecasts and decision support systems for drought prone agriculture**
Dr. Jeff F. Clewett, Department of Primary Industries, Australia

15:00 Break

15:30 **Early warning system against cool summer damage: Case of Northern Japan**
Dr. Masaharu Yajima, National Agricultural Research Center for Tohoku Region

16:30 **ENSO Impacts on Food Crop Production and the Role of CGPRT Crops in Asia and the Pacific**
Mr. Shigeki Yokoyama, Project Leader, ELNINO Project, CGPRT Centre

17:30 Discussion

19:00 Welcome dinner

Wednesday 18 September 2002

8:30 ELNINO Project Country Reports Moderator: Dr. R. N. Concepcion, Mr. S. Yokoyama

Indonesia
Dr. Bambang Irawan (National Expert)
Dr. Nizwar Syafa'at (Commentator)

9:30 **Malaysia**
Mr. Ariffin bin Tawang (National Expert)
Mr. Wong Hin Soon (Commentator)

10:30 Break

11:00 **Papua New Guinea**
Dr. Sergie K. Bang (National Expert)
Dr. R.D. Ghodake (Commentator)

12:00 Lunch

13:00 **Philippines**
Dr. Florentino C. Monsalud (National Expert)
Dr. Albert P. Aquino (Commentator)

14:00 **Thailand**
Mr. Thamrong Mekhora (National Expert)
Dr. Wirat Krasachat (Commentator)

15:00 Break

15:30 Discussion

17:00 **Closing Remarks**
Mr. Kiran Pyakuryal, Chief, Rural Development Section, PRUDD, ESCAP

19:00 **Working dinner for ELNINO project**

- Review the progress of the project regarding outputs and impacts.
- Contents and structure of the final reports.
- Proposal of in-country seminars.

Thursday 19 September 2002

7:30 Field trip
Visit and discussion with a farmer group of organic farming at a highland horticultural area, in a suburb of Cebu city.

12:00 Lunch

Appendix 2: List of Participants

Joint Workshop

"Coping against El Nino for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific"

Cebu City, the Philippines
17 – 19 September 2002

No.	Name/title/address
A. PRINCIPAL GUESTS	
1. PHILIPPINES	**Hon. Pablo P. Garcia** Governor of Cebu Province Philippines
2. PHILIPPINES	**Hon. Ernesto M. Ordonez** Undersecretary Department of Agriculture Elliptical Road, Diliman, Quezon City, Philippines
3. PHILIPPINES	**Mr. Sang Mu Lee** Resident Representative Food and Agriculture Organization Philippines
4. PHILIPPINES	**Mr. Eiji Ueno** First Secretary (Agriculture) Japanese Embassy Manila, Philippines
5. JAPAN	**Mr. Tomohide Sugino** Senior Researcher Research Planning Section Research Planning and Coordination Division Japan International Research Center for Agricultural Sciences (JIRCAS) 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan

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6. UN ESCAP	**Mr. Kiran Pyakuryal** Chief Rural Development Section Population and Rural and Urban Development Division UN-ESCAP Rajdamanern Nok Avenue Bangkok 10200, Thailand
B. KEYNOTE SPEAKER	
7. AUSTRALIA	**Dr. Jeff F. Clewett** Principal Scientist and Leader, Landscape Systems Queensland Centre for Climate Applications Department of Primary Industries Tor Street, Toowoomba, Qld 4350, Australia
8. THAILAND	**Dr. Felino P. Lansigan** International Water Management Institute Southeast Asia Regional Office 7th Floor, IFRPD Building Kasetsart University P.O. Box 1025, Bangkok, Thailand
9. JAPAN	**Dr. Masaharu Yajima** Director Department of Biology and Environmental Sciences National Agricultural Research Center for Tohoku Region 4, Akahira, Shimokuriyagawa Morioka City, Iwate Pref., 202-0198 Japan
C. REGIONAL ADVISOR	
10. PHILIPPINES	**Dr. Rogelio N. Concepcion** Director Bureau of Soils and Water Management Department of Agriculture Soils Research and Development Center Building Elliptical Road, Diliman, Quezon City, Philippines

No.	Name/title/address
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11. INDONESIA	**Dr. Bambang Irawan** Researcher Center for Agro-Socio Economic Research and Development (CASERD) Jl. Achmad Yani 70, Bogor 16161, Indonesia
12. MALAYSIA	**Mr. Ariffin bin Tawang** Deputy Director Economic and Technology Management Research Centre Malaysian Agricultural Research and Development Institute (MARDI) PO. Box 12301, GPO 50774, Kuala Lumpur, Malaysia
13. PAPUA NEW GUINEA	**Dr. Sergie Kopen Bang** Principal Scientist National Agricultural Research Institute (NARI) Aiyura Valley, P.O. Box 384, Kainantu Eastern Highland Province, Papua New Guinea
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54.	**Eric Remoroza** Instructor Cebu National University Cebu City, Philippines
55.	**Romeo A. Rigor** Director Philippine Crop Insurance Corporation Cebu City, Philippines

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60.	**Necias A. Vicoy** Provincial Agriculturist – Cebu Province DA Cebu Province Cebu Capital, Cebu City, Philippines
G. CGPRT Centre	
61. Dr. Nobuyoshi Maeno	Director
62. Mr. Shigeki Yokoyama	Project Leader

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