Economic and Social Commission for Asia and the Pacific

CGPRT Centre WORKING PAPER No. 61

Stabilization of Upland Agriculture under El Nino Induced Climatic Risk: Impact Assessment and Mitigation Measures in Malaysia

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

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Humid Tropics of Asia and the Pacific

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List of Acronyms

ASMC	ASEAN Specialized Meteorological Center
API	Air Pollution Index
ENSO	El-Nino Southern Oscillation
HTTF	Haze Technical Task Force
IBBP	International-Biosphere Program
IHDP	International Human Dimension of Global Environmental Change Program
IRPA	Intensification of Research in Priority Area
MADA	Muda Agricultural Development Authority
MMS	Malaysian Meteorological Services
MARDI	Malaysian Agricultural Research and Development Institute
NAP	National Agricultural Policy
NHAP	National Haze Action Plan
NOAA	National Oceanic and Atmospheric Agency
RHAP	Regional Haze Action Plan
START	Global Change, System for Analysis, Research and Training
SOI	Southern Oscillation Index
TSP	Total Suspended Particule
WMO	World Meteorological Organization
WCRP	World Climate Research Program

Currency conversion: US$1 = RM3.80 (fixed rate, all years)

Foreword

The El Nino-induced abnormal weather tends to be increasing in its frequency of occurrence, magnitude, duration and irregularity in recent years. 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 (ELNINO)", since April 2000 in collaboration with partners from five countries: Indonesia, Malaysia, Papua New Guinea, the Philippines and Thailand.

It is my pleasure to publish **Stabilization of Upland Agriculture under El Nino Induced Climatic Risk: Impact Assessment and Mitigation Measures in Malaysia** as one of the results of the project. The volume covers various topics such as historical overview of El Nino-induced abnormal weather, physiological interaction between climate variability and agricultural production, impacts on major commodities and mitigating measures. I believe the report will support the preparation of strategic proposals for technologies, farm management and administrative policies to stabilize upland crop production and farm economy leading to sustainable rural development in the region.

I thank Mr. Ariffin bin Tawang, Mr. Tengku Ariff bin Tengku Ahmad and Dr. Mohd. Yusof bin Abdullah for their earnest and fruitful work. This interdisciplinary study could only be accomplished with the continuous support from Malaysian Agricultural Research and Development Institute (MARDI). Dr. Rogelio N. Concepcion, Bureau of Soils and Water Management, Department of Agriculture, the Philippines, and Mr. Shigeki Yokoyama provided useful comments and guidance at various stages of the study as the regional advisor and the project leader, respectively. I also thank Dr. Douglas R. Stoltz for his editing services throughout the publication of the report. Finally, I would like to express my sincere appreciation to the Government of Japan for its support in funding the project.

November 2001

Nobuyoshi Maeno
Director
CGPRT Centre

Acknowledgements

The study on 'Stablization of Upland Agriculture and Rural Development in El Nino Vulnerable Countres' was sponsored by the UN-ESCAP CGPRT Centre as part of a regional study involving selected Asian countries. In this regard, we are very grateful for the opportunity given to our country to be one of the participants in this study. We are also very grateful to the CGPRT Centre for the opportunity given to us to represent the country in conducting this study. For this, we appreciate the contribution of Dr. Nobuyoshi Maeno, Director, CGPRT Centre. His deep interest, dedication and leadership motivated us to undertake the study.

Special thanks are due to the Director General of the Malaysian Agricultural Research and Development Institute (MARDI), Dr. Saharan Haji Anang, the Director of the Economics and Technology Management Research Centre and Dr. Ahmad Zamzam Mohamed, the former Director of the Strategic Environments and National Resources Research Centre, MARDI for allowing us to be involved in the study. Their understanding and support are highly appreciated.

Our utmost gratitude is directed to the project leader, Mr. Shigeki Yokoyama, and Dr. Roger Conception, the regional advisor. Both of them were instrumental in developing the framework of the study as well in providing advice and guidance to ensure the successful implementation of the study.

Many other individuals also contributed in one way or another to this study. Most of the weather data were sourced from the Malaysian Meteorological Services. In this regard, we would like to express our special thanks to Mr. Azhar bin Ishak, the Meteorological Officer and his staff at the Climate Division, and Mrs. Leong Chow Peng, the Director, Environmental Studies Division. Special thanks are also due to Mr. Wong Hin Soon, Head of Planning and Evaluation Division, Mr. Teoh Weng Chaw, Deputy Head of Engineering Division and other staff of MADA who provided good insight on water management strategies in the Muda Agricultural Development Authority (MADA). Similar thanks are extended to Mr. Mohd Nasir Yusof, General Manager of Gula Padang Terap Berhad, a sugarcane plantation, and his management team; and Mr. Ahmad Rodzi, assistant manager of FELDA Bukit Tangga and Dr. Masri Muhamad, Head of MARDI Research Station Bukit Tangga for sharing their experiences with regards to the impact of the last El Nino with the study team.

In the Economic and Technology Management Research Centre, our colleague, Mrs. Salbiah Husin, Head of Statistical Program, deserves special mention for her efforts in running the regression model. We would also like to express our thanks to the supporting staff of the Centre, especially Mr. Suhaimi Talib and Mr. Samari Mohd Senang for their efforts in data collection and assembly, and finally, to Mrs. Norashikin Idris and Mrs. Norzahrilah Jamaluddin for their untiring efforts and dedication in typing the report.

MARDI, Serdang
April, 2001

Ariffin Tawang
Tengku Mohd Ariff Tengku Ahmad
Mohd Yusof Abdullah

Executive Summary

For the past few decades, the agricultural sector as a whole has been fairly stable, which has influenced the economic stability of many nations. Translated at the farm level, this has led to a fairly stable and predictable income of the farm community at large. However, for the last twenty years, the incidence of abnormal weather variation has been more frequent and rampant, brought up predominantly by El Nino. In this country, the El Nino induced weather change has resulted in a prolonged dry season, which has led to severe drought and increased temperatures. This was further compounded by the formation of haze due to the large scale burning of forest and plantations for land preparation. These phenomena brought serious implications on farm productivity and land use patterns. This study aims to describe, analyze and quantify the impact of El Nino induced climate variability on the agricultural sector and rural economy, and to propose measures to mitigate the impact so as to stabilize agricultural production and the welfare of the rural population at large.

Malaysia possesses a typical tropical climate, where the temperature and humidity are high and fairly uniform, with abundant rainfall, good cloud cover all the year round, and small seasonal variation in solar radiation. However, the recent El Nino resulted in acute rainfall deficit, fewer rainy days and increased daily temperature. Air quality, measured in terms of Total Suspended Particulates (TSP) also increased dramatically. For all regions in the country, the last El Nino episode resulted in rainfall deficit ranging between 5% to 26%, an increase in temperature between 0.5°C to 1.7°C, and TSP readings increased by 1.6 to 3.5 fold.

Weather plays a major role in determining crop yields, including the year to year variability and the spatial patterns of global agriculture. Environmental stresses such as drought, high temperature, and air pollution are major limiting factors to crop productivity in the tropics. The impact of these climatic stresses on crop productivity evaluated using morphological, physio-biochemical and yield responses indicated that climate variability does affect the agricultural sector in Malaysia. Subsequently, this will be a threat to national food security and the economic contribution from the agricultural sector.

The main environmental variables for crop growth are rainfall, temperature, solar radiation and atmospheric gases, particularly carbon dioxide and oxygen. Any change in these factors would have a significant impact on productivity and land use patterns. Under dryland conditions two types of stresses are commonly encountered, namely water stress and high temperature stress. The effects of high temperature stress are often confounded with those of water stress, because drought is usually accompanied by high temperature, which increases the rate of transpiration and hastens the occurrence of injurious dehydration.

Lack of water influences crop growth in many ways. The effect depends on the severity, duration, and time of stress in relation to phenological stages of growth. Generally, most crops grow well with a mean annual precipitation greater than 2000 mm and a minimum monthly rainfall of about 150 mm. Crop productivity decreases linearly with decrease in rainfall and is severely affected when mean annual precipitation falls below 1000 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. Nearly all annuals, particularly vegetable crops, are sensitive to drought during two periods: flowering and fruit development (tuber formation or head formation). Depending on the vegetable type, this period may extend from 3 to 10 weeks. 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.

Apart from water and temperature, 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 solar 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% 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 are presumably due to haze that previously occurred within the previous three months.

Quantification of the impacts of the El Nino on the performance of specific commodities and the subsequent social and economic impacts was a difficult task. This was due to the difficulty in isolating the 'El Nino-related effects' from other effects. Since yield was the sole basic criteria to evaluate crop performance and output, the evaluation can be biased due to the effects or other variables, which could be more significant. These include a number of other variables that could effect biological yield over time such as technical change, input use and better crop management practices. It is also possible that non-weather related variables such as economic factors also affect yield performance. To reduce the bias for technical change, losses due to weather changes for each respective year were calculated based on a five-year interval moving maximum. A major assumption here was that no technical change takes place within the five-year interval. For the major crops such as oil palm, rubber and rice, this analysis was followed by a simple "yield function regression analysis", where the significant variables that affect crop performance were identified.

The analyses carried out provided strong evidence of the negative effects of the El Nino on Malaysian agriculture. Total losses to agriculture as a result of poorer performance of oil palm, rubber and rice due to the El Nino were estimated to be more than RM 3.3 billion for the 1980 to 1999 period. Hardest hit was the palm oil industry with estimated losses of RM 2,651 million, followed by rubber with about RM 357 million and rice with almost RM 218 million. These estimated losses do not take into account the secondary spin-off losses resulting from loss of production value of other downstream and derivative products of palm oil, rubber and rice. Results from the regression analyses also indicate that the El Nino episodes significantly affect yield. Results also show that rainfall and total suspended particulate were important variables that affect yields of oil palm and rice. The analyses for the other sub-sectors including fruits, vegetables, sugarcane, fisheries and selected livestock industries, showed no evidence that El Nino had significantly resulted in productivity losses.

The country also incurred loss in terms of foreign exchange as a result of the loss from potential export earnings of palm oil and the need to import more rice to fulfill the country's demand. Based on the fact that about 75% of Malaysia's production of palm oil in 1998 was exported, the total loss in exports in the EY was at RM 2,129 million. For rubber foreign exchange losses were estimated at RM 179 million.

The importance of mitigating measures was given special consideration in the report. In fact, the marginal impact of climate on agricultural production could be due to the various mitigating measures already in place. For one, the country was not caught unprepared, at least for the El Nino of 1997/98. Ample warnings and forecasts were provided by the Department of the Environment based on their continuous monitoring of weather patterns. The presence of an adequate and efficient supply of irrigated water, especially during the planting and growing period, increased irrigation efficiency with the introduction of drip irrigation, water recycling, water harvesting and other water conservation strategy helped in mitigating the possible repercussions of water stress on crops, especially among the annual crops. Other measures include the introduction of a more stringent measure by the government, such as the amendment of the Air Quality Index (1974), to provide stricter regulation and stiffer penalties to ensure maintenance of air quality. In the plantation sector, the ‘zero burning policy’ was introduced, supported by intensive aerial and land surveillance. Since the haze incidence was the consequence of transboundary movement of pollutants, the ASEAN Regional Haze Action Plan was introduced to complement and support the National Haze Action Plan.

In a longer-term strategy, the existing national capability for monitoring the development and evolution of El Nino must be strengthened. It is pertinent that the increased capacity to predict climate variability, and subsequently establish the relationship between climatic parameters and crop yields in the form of expert systems, would help in establishing the necessary tools for prediction and subsequent development of mitigating measures. This would facilitate decision-making processes at different levels. Such approaches could provide a dependable early warning system, which should be able to advise farmers on what crops to grow, where and how much to meet the impending change in weather. However, this would require better access to technical and financial resources for the relevant authorities. Similarly, research and development support in the areas of water saving technology, drought resistant varieties, development of expert systems and precision farming need to be strengthened. These must go hand in hand with other supportive policy and legislation, public awareness and education. Obviously, irrigation is the most important tool to counter the effect of drought. Therefore at the farm level, the existing water supply infrastructure must be efficiently designed, operated and maintained so as to reduce any wastage. Introduction of a water pricing policy could be considered to reduce water wastage during farm operation. The concept of crop insurance and other financial strategies, which have not been exploited yet in this country, should be given serious consideration to ensure the ability of farmers to weather droughts and subsequent crop failures.

Whilst drought is a natural phenomena that can not be altered, haze is basically man made and could be handled. The existing mechanisms in place, in terms of monitoring, legal and institutional arrangements and stronger regional cooperation, would only be meaningful if there were strong partnerships, commitments and the capability of enforcement. Apparently, these are among the weak links. This must be strengthened, and acted upon diligently.

1. Introduction

Climate plays a major role in determining crop yield, and hence the final crop production. Therefore, the welfare of a nation could be affected very much by any abnormality in climate. Particularly for the countries in the tropics, abnormal climate would have a strong implication on the performance of major economic sectors, including the agricultural sector. It is thus essential that the links between climate variability and agricultural productivity be understood, both to optimise agricultural production under the so called 'normal climate', and more importantly to identify and establish the necessary mitigating measures during the abnormal climatic conditions.

1.1 El Nino induced climate variability and agricultural development

At the onset, it must be made very clear that climate variability in the context of this study relates to climate variability rather than climate change. Climate variability or abnormal climate refers to the short or medium term fluctuations of the mean climate state at some period in time, such as the El Nino and La Nina events. On the other hand, climate change refers to the fundamental shift in the mean states of the climate that pertains to longer-term trends, as in the case of global warming. Whilst the terms climate and weather change could been used interchangeably with that of climate and weather variability or abnormality in the subsequent write-up, the underlying emphasis is on the El Nino induced climate or weather variability and abnormality rather than climate and weather change per se.

Over the years, the agricultural sector performance as a whole had been fairly stable, with little periodic variation. This was possible partly due to the similar stability in climate. Translated at the farm level, this has led to a stable and predictable livelihood for the farm community at large. However, the more frequent and rampant abnormal weather phenomena, brought up predominantly by El Nino related abnormal weather could significantly affect this stability.

Hence, the recent trend of an increase in irregularity and frequency of El Nino occurrence is one risk that cannot be taken lightly. It could create a devastating impact, particularly on food production and rural livelihood. In Malaysia, the El Nino induced weather change has resulted in prolonged dry seasons and severe drought, higher temperature and deterioration in air quality and light penetration. Theoretically, these changes could bring serious implications to crop growth and yield, hence to the economic contribution from the agricultural sector. By virtue of the fact that large areas were affected by this abnormal weather, covering countries in the Asia Pacific region, the aggregate decline in agricultural production could be very significant. This could lead to serious implications for food availability, foreign exchange and livelihood of the peasant farmers within these countries. On a global scale, a sudden decline in food could create an acute shortage in the world market, which could result in sharp increases in world prices. Thus, the whole world could be affected by such price increments, for both food and non-food agricultural produce. Hence, a 'strong' and devastating El Nino, if remaining unchecked and without proper mitigating measures, could trigger an environmental disaster and pose serious problems in food security and agricultural raw materials availability, specifically within the Asia-Pacific region, and the world as a whole.

Generally, a large scale El Nino episode could seriously affect under-developed and developing countries where the agricultural sector constitutes a big chunk of economic contribution including foreign exchange and rural employment. Similar risk, however should not be discounted among the developing countries, even though they are better prepared for such problems. For example, in both developing and under-developed countries in the region, the existing institutional arrangement and infrastructure investment to mitigate the impact of climate change are not adequate. In fact, less and less farm infrastructure investment had been provided in the past decades. For instance, the budget allocation for upgrading and improvement of the irrigation and drainage facilities in Malaysia within the eight rice-growing areas in the country has not shown significant increases. Such being the scenario, it is probable that the most vulnerable groups, which would have to bear the greatest impact of the El Nino induced climate change, would be the small and resource poor farmers in the rural areas. They are also among the poorest segment of the population, in spite of the fact that they are the main providers of food in the country.

It is with this argument that the study was formulated, basically to describe and quantify the impact of El Nino induced climate variability on agricultural production and the rural economy, and to identify the relevant mitigating measures that need to be established or enhanced in order to reduce the impact of climate variability.

1.2 Scope and objectives of the study

The adverse effects of the previous El Nino episodes had created an immense interest on studies related to this abnormal weather. However, most of these studies were focused on establishing the impacts of the deteriorating air quality brought about by El Nino induced climate change (in the form of haze), in terms of welfare loss for selected sectors. Studies on the effect on agricultural production, particularly on food products had not been given similar emphasis. Subsequently, a quantifiable assessment of the impact of El Nino on the major agricultural commodities in the country was still lacking. This study will hopefully be able to provide some indications on this aspect, hence filling this information gap.

In the conduct of the study, both food and non-food agricultural commodities will be analyzed. In the non-food sector, oil palm and rubber are selected. These two commodities are the source of growth in the agricultural sector, accounting for 54% of total agricultural value added, with combined export earning of about RM 24 billion, and providing employment to 650,000 farm families and 130,000 estate workers in 1998. For the food sector, the study will consider the whole 'food basket' consisting of rice, fruit and vegetables, livestock products and fisheries. Rice is given special consideration since it is the staple food of the country, and is always associated with food security issues. As these commodities are almost entirely produced by resource poor small farmers, a small change in production brought about by abnormal weather could create a big impact on their farm income. Rice and vegetable farmers, and to some extent the fruit growers, are more susceptible to El Nino induced abnormal weather due to the sensitivity of their crops to water deficiency.

The overall objective of the study is to measure the impact of El Nino induced climate variability on the agricultural sector, and identify measures to mitigate the impact so as to stabilize agricultural production and rural development, particularly in Malaysia. Specific objectives are as follows:

i. To collect and analyze data and information on El Nino related abnormal weather changes, and establish the historical pattern of El Nino related environmental hazards.
ii. To conduct a comprehensive literature review on the impact and damage of El Nino related environmental hazards, particularly on the agricultural sector in this country.
iii. To quantify the impact of El Nino on the agricultural sector, focusing on the important commodities in the El Nino vulnerable areas, in terms of production and socio-economic implications, at both the regional and national level.
iv. To assess the current institutional and structural capabilities to minimize the impact of El Nino.
v. To propose new and improved strategic approaches including short and long term measures to reduce the impacts of the El Nino.

1.3 Organization of the study

This report is organized in eight main chapters. The first chapter dealt with the general rationale of the study, to relate the importance of assessing the El Nino induced weather variability and agricultural development. This chapter also highlighted the objectives of the study. Chapter 2 describes the general characteristics of the weather in the country, including a brief description on some of the weather related phenomena prevailing in the country. It also identifies areas which are most vulnerable to the El Nino induced weather change. This chapter also provides an overview of the incidence of El Nino in terms of frequency and intensity and impacts on specific economic sectors, especially with regards to the El Nino of 1997/98, which was considered the strongest and most intense. A description of the role of agriculture in the Malaysian economy is highlighted in Chapter 3, including the structural composition of Malaysian agriculture, trend analyses on area planted, yield, production, import and export for both food and primary commodities, including livestock and fisheries. This chapter also discusses the role of the various agricultural development and environmental management institutions which are relevant to study.

The biological interaction between climate variability and agricultural production, as a basis for establishing the impact of climate on agricultural production, is discussed in Chapter 4. It takes into consideration climate variability with respect to water availability, temperature, radiation and other anthropogenic stress including the haze. The most important part of the report, which is analyzing and quantifying the economic impact of El Nino induced weather on agricultural production and rural development, is presented in Chapter 5. It describes the methodology adopted, specific commodity effects with regard to change in productivity, food security and other socio economic impacts. Chapter 6 describes the existing mitigating measures and procedures already in place to reduce the effect of El Nino. New and improved strategies and recommendations to the government and industry are put forward for consideration in Chapter 7, followed by a conclusion of the study in the last chapter.

2. El Nino and Climate Variability

This chapter provides a brief description of the general characteristics of the Malaysian climate by region. This represents the characteristics of 'normal' climate as a basis for comparison with the 'abnormal' El Nino induced climate variability. The chapter also provides some insight on El Nino incidence and effects on the climate. Special focus is given to the El Nino episode of 1997/98, considered the most 'devastating' compared to earlier episodes. Some of the socio-economic impacts, based on past studies, are presented to give some indications of their effects on selected sectors.

2.1 General characteristics of the Malaysian climate

Malaysia consists of the states in Peninsular Malaysia, Sabah and Sarawak. It is situated in an equatorial region, hence the typical tropical climate. Thus, the general features of Malaysia's climate are high and uniform temperature, high humidity and abundant rainfall. There is always good cloud cover all the year round. During the monsoon period, it is common to have days with no sunshine at all. By virtue of its equatorial climate too, there is no cold season due to the small seasonal variation in incoming solar radiation over the year. Variations in temperature are usually small and mainly due to the degree of cloudiness. More detailed climatic characteristics, which are relevant to agricultural production, are presented below.

2.1.1 Rainfall distribution

Total annual rainfall is high, exceeding 1600 mm everywhere in the country, and well over 2500 mm in many locations (Table 2.1). On a global scale, this could be considered as one of the wettest regions in the world. The main reason for the high rainfall is the marine environment of the country. The uplifting of the very humid and warm air masses in thick layers after a long journey over the tropical seas results in plentiful rainfall all year round. The exception is for some parts of the country, where dry seasons do occur, especially in the northwestern part of the peninsular region. This is the region that is more vulnerable to drought.

Table 2.1 Mean rainfall distribution by month, between regions.

Region	Peninsular Malaysia						Sabah	Sarawak	Mean
	Northwest	West Coast	South	East Coast	Northern Interior	Central Interior			
Jan	27.1	127.2	120.8	171.3	122.5	122.6	109.7	666.7	183.5
Feb	55.7	133.7	113.9	105.4	67.2	124.5	74.4	494.7	146.2
Mar	114.6	187.5	176.9	153.5	111.7	170.7	50.7	342.6	163.5
Apr	137.1	244.3	211.8	145.4	102.2	197.3	108.2	278.5	178.1
May	133.4	222.7	196.3	156.6	135.7	179.0	216.1	254.6	186.8
Jun	120.1	148.3	160.1	148.1	163.8	127.6	274.2	209.4	168.9
Jul	199.8	161.9	179.3	145.3	146.2	105.6	267.6	194.1	175.0
Aug	235.7	186.3	186.1	167.6	186.4	154.8	272.1	224.7	201.7
Sep	204.5	244.9	198.4	206.0	255.0	176.1	278.4	263.6	228.4
Oct	316.0	310.1	216.6	234.5	233.5	200.4	348.9	334.5	274.3
Nov	245.0	266.4	244.3	443.9	426.1	242.8	298.3	353.6	315.0
Dec	120.1	196.9	197.9	421.7	459.1	198.3	226.2	475.8	287.0
Total	**1908.9**	**2430.1**	**2202.3**	**2499.5**	**2409.5**	**1999.8**	**2524.7**	**4092.7**	**2508.4**

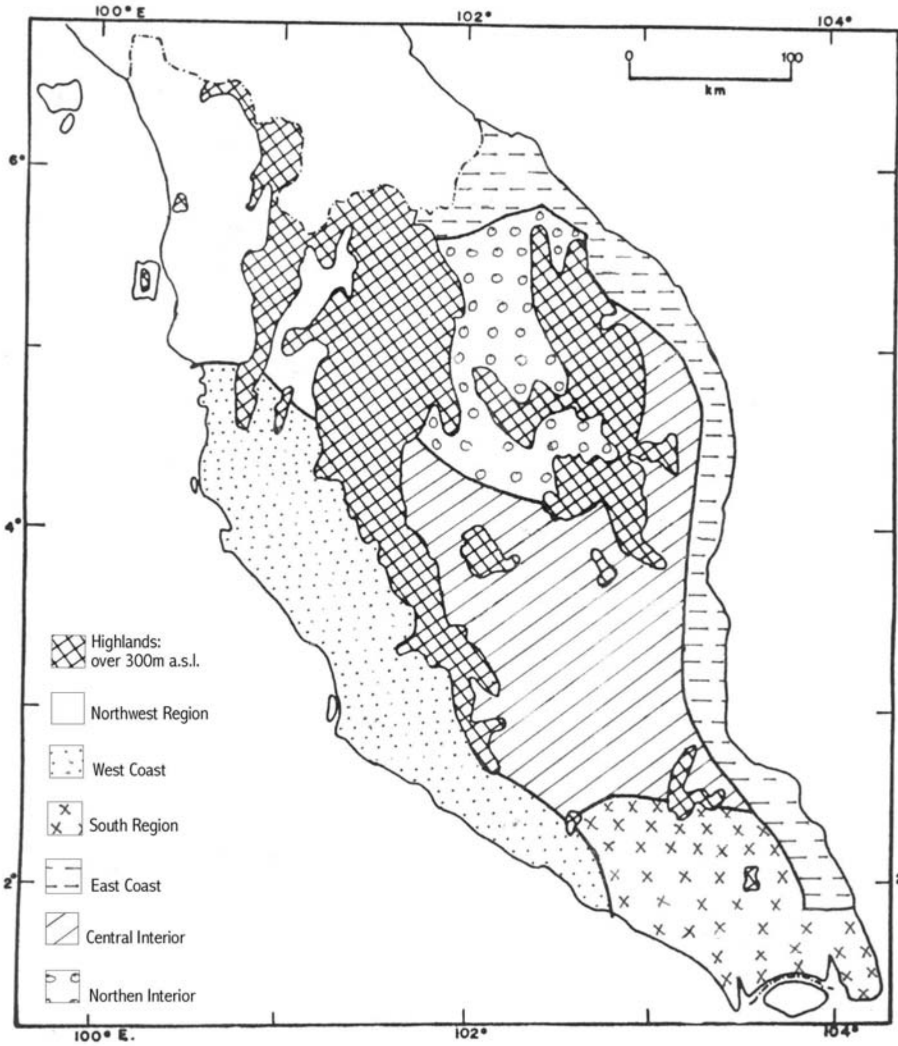
Source: Malaysian Meteorological Services (2001).

In spite of the fairly uniform rainfall over the country, there is a distinct variation in terms of its distribution between regions. This is due to differences in topographic features and the seasonal wind flows (Malaysian Meteorological Services 2001). During the northeast monsoon season, the exposed areas of the east coast of Peninsular Malaysia, western Sarawak and the northeast coast of Sabah experience heavy rainy spells. The inland areas, which are sheltered by mountain ranges, are relatively free from this influence. The monthly rainfall in various regions in Peninsular Malaysia, Sabah and Sarawak is summarized in Table 2.1. The region with the least annual rainfall is the northwest region, at 1909 mm per year as compared to the national average of about 2610 mm.

Peninsular Malaysia

The pattern of rainfall distribution for the main regions in Peninsular Malaysia is presented below, based on meteorological data from selected weather stations from the respective regions. The respective regions are depicted in Figure 2.1, and they form the basis for the development of the agro ecological zones of the country.

Figure 2.1 Rainfall pattern by region for Peninsular Malaysia.



Source: Nieuwolt et al. (1982).

The northwest region

The main climatic feature for the region is the presence of a distinct and regular dry season, especially from December to March. The duration of the dry period is 2 to 4 months. The main rainy period is September to November, and the secondary period April to May. The duration of the dry season decreases towards the southern part of the region. This is the region where drought is quite frequent.

The west coast region

The region has a semi-annual mode with two maxima coinciding with the two inter monsoon periods of April to May and September to November. The dry period is rather irregular, and of shorter duration of not more than one month. The dry period occurs mostly in the months of January and February, followed by a second dry period between June and July.

The south region

The region is characterised by the absence of a dry season. Dry spells rarely last more than a few weeks, and appear rather irregularly. The rainfall is fairly well distributed all year round.

The east coast region

The region registers a single peak of heavy rainfall at the end of the year, which is associated with the northeast monsoon period. Hence, the months of November, December and January are the wettest months. The dry season is rather regular, with June and July as the only dry months.

The central interior

The main characteristic of the region is the presence of two dry seasons of about equal intensity, the first around February - March, and the second in July. Rainfall is rather uniform, with rains occurring mostly in the afternoon.

The northern interior

The main climatic features are similar to those of the northeast east region, except that the amount of rainfall is lower due to its interior location. There is a strong probability of drought in the month of June to August in the region.

Sabah

The two rainfall regimes of two maxima (June and October) during the southwest monsoon period and two minima (February and August) are fairly distinct. However, in the central parts of the state, the rainfall level is lower and is more evenly distributed.

Sarawak

There is a distinct rainfall regime of one maximum (Dec. - March) and one minimum (June - July) in Sarawak. The inland areas of the state, however, receive quite evenly distributed annual rainfall.

Concurrent with the rainfall distribution, the number of monthly rainy days shows an almost identical pattern (Table 2.2). Rainy days are defined as days which registered at least 0.1 mm of rain. As a whole, and irrespective of duration, about 50% of the days in a year are rainy days. For all the regions, the northwest region has the least number of rainy days in a year, at 167 days, an equivalent of about 45% of the total days in a year.

Table 2.2 Mean rainy days by region.

Region	Peninsular Malaysia						Sabah	Sarawak	Mean
	Northwest	West Coast	South	East Coast	Northern Interior	Central Interior			
Jan	3.7	11.3	11.4	14.0	15.1	14.6	12.1	24.7	13.4
Feb	4.8	11.3	10.4	9.9	6.5	8.4	8.9	20.6	10.1
Mar	9.4	14.8	14.6	11.6	10.9	12.4	8.4	20.6	12.8
Apr	14.9	18.0	17.1	12.5	10.8	13.1	10.9	19.6	14.6
May	16.9	17.2	16.7	13.3	12.2	14.3	16.2	19.2	15.7
Jun	13.8	12.5	14.1	12.3	12.4	8.7	16.1	16.7	13.3
Jul	16.3	13.5	15.7	12.9	13.3	12.4	16.8	16.2	14.6
Aug	17.3	15.2	16.0	14.7	16.6	11.3	16.5	17.4	15.6
Sep	20.1	18.1	16.1	16.0	19.1	16.2	18.2	19.2	17.9
Oct	21.8	21.5	18.8	18.6	20.1	17.6	19.8	22.8	20.1
Nov	17.9	20.9	20.3	21.7	22.2	17.9	19.4	24.1	20.5
Dec	10.1	16.0	17.3	19.7	18.7	19.2	16.7	25.4	17.9
Total	**167.0**	**190.2**	**188.6**	**177.3**	**177.9**	**166.1**	**179.9**	**246.6**	**186.5**

Source: Malaysian Meteorological Services (2001).

These two factors, total precipitation and the related number of rainy days are important factors in agricultural crop performance. This is because insufficient moisture would reduce production, while surplus could damage the plant.

2.1.2 Temperature distribution

Malaysia has uniform temperature throughout the year, with annual variation at less than 2.5°C. The mean temperature in the lowlands is 26°C to 28°C, and only in the highlands does it drop below 20°C. The homogeneity of temperature is primarily due to the low latitudinal position of the country and the predominance of marine air masses (Nieuwolt 1982). However, the daily range of temperature is large, from 5°C to 10°C at the coastal stations and from 8°C to 12°C at the inland stations (Malaysian Meteorological Services 2001). Generally, the days are hot and the nights are relatively cool. The mean monthly temperatures for major regions in the country are indicated in Table 2.3.

Table 2.3 Mean monthly temperature by region.

Region	Peninsular Malaysia						Sabah	Sarawak	Mean
	Northwest	West Coast	South	East Coast	Northern Interior	Central Interior			
Jan	26.8	26.8	25.9	25.8	25.0	25.6	26.2	25.5	26.0
Feb	27.6	27.1	26.5	26.3	25.8	26.4	26.4	25.8	26.5
Mar	28.0	27.4	26.7	26.9	26.6	27.1	27.1	26.2	27.0
Apr	28.0	27.5	26.8	27.4	27.3	27.5	27.8	26.6	27.4
May	27.7	27.6	26.9	27.5	27.2	27.5	27.7	26.9	27.4
Jun	27.4	27.5	26.8	27.2	26.9	27.1	27.5	26.8	27.1
Jul	26.9	27.1	26.3	26.9	26.6	26.7	27.2	26.6	26.8
Aug	26.8	26.9	26.2	26.7	26.3	26.7	27.3	26.5	26.7
Sep	26.6	26.6	26.2	26.6	26.0	26.5	27.0	26.3	26.5
Oct	26.4	26.5	26.3	26.5	25.9	26.5	26.9	26.0	26.4
Nov	26.3	26.4	26.0	26.0	25.4	26.1	26.7	25.8	26.1
Dec	26.2	26.4	25.8	25.7	24.7	25.4	26.6	25.6	25.8

Source: Malaysian Meteorological Services (2001).

There exist, however, a few exceptions to the uniformity of temperatures between areas. This is due to many factors. The rainy seasons during monsoons in the east coast region in the months of December to February, differences in elevations as in the highlands, which are able to reduce temperature by about 0.6°C for every 100-meter height, and the higher temperature regime in the cities and urban areas, influence the temperature. Overall, temperature differences between days are small and there are no sudden and large changes in temperature as in temperate climates.

2.1.3 Winds

Wind direction is generally controlled by the monsoons. They show clear periodic changes, with northern and easterly winds dominating during the northeast monsoon season, and westerlies prevailing during the southwest monsoon season. The northeast monsoon starts in November through March, where the winds can reach 30 knots or more, whilst the southwest monsoon usually starts in May and ends in September with light winds at about 15 knots (Malaysian Meteorological Services 2001). During the months of April to November, when typhoons frequently develop over the west Pacific, the northwest coast of Sabah and Sarawak are exposed to the southwesterly winds which can reach 20 knots or more.

2.1.4 Relative humidity

Malaysia has a high relative humidity, which is defined as the ratio between the actual water vapor content and the maximum amount that the air can retain at the same temperature. For of agriculture purposes, this is an important indicator with implications in many plant physiological processes. The mean daily relative humidity of the country ranges between 70% and 90%. Some weather stations register values as high as 100%, especially during the night. Under such circumstances, the formation of dew and night fog is fairly common. The relative humidity has a strong inverse correlation with temperature. Falling temperatures result in an increase in relative humidity and vice-versa.

2.1.5 Sunshine and cloudiness

Sunshine (and relatedly the solar radiation) is important in agricultural production, because it controls photosynthesis. Being within the equatorial region, the country has abundant sunshine. However, the total hours of sunshine do vary between regions. Nieuwolt (1982) indicated a correlation between rainfall and sunshine hours. The highest sunshine hours were recorded in regions where dry seasons occur regularly, while in areas where dry seasons are rare, the total sunshine is lower. Cloudiness is the opposite of sunshine, and it has a strong effect on temperature. By virtue of the fact that cloud cover is quite prominent in this country as a whole, Malaysia receives about six hours of sunshine per day, ranging from 3.7 hours per day in the month of January in Kuching, Sarawak to 8.7 hours per day in the same month in Alor Setar, Kedah, which is situated in the northeastern part of Peninsular Malaysia (Malaysian Meteorological Services 2001).

2.2 Weather related phenomena

The Malaysian Meteorological Services (2001) identified several weather related phenomena that frequently affect the country. A brief account of these phenomena is presented.

2.2.1 Monsoon

The monsoon period is characterized by strong winds, which blow persistently with heavy rainfall. There are two main monsoon regimes, the stronger northeast monsoon (November to March) affecting the east coast states of Peninsular Malaysia and western Sarawak and the relatively drier southwest monsoon (May to September) throughout the country, except Sabah. The transition period in between the monsoons is known as the inter-monsoon period.

Thus, the northeast monsoon is the major rainy season in the country, bringing heavy rains and severe flooding. During this period, the monthly rainfall in some affected areas ranges between 400 and 700 mm per month, which could contribute substantially to the area's annual precipitation. The drier southwest monsoon, with monthly rainfall between 100 and 150 mm, is attributed to the relatively stable atmospheric condition in the equatorial region. The inter-monsoon periods are characterized by light winds, clear skies and thunderstorms in the afternoon. Temperatures are not affected by the monsoons, except during the northeast monsoon, due to strong cold winds and the cloudy sky.

The impact of the monsoons on the socio-economic activities in Malaysia is tremendous (Sham Sani 1998). Strong winds, rough seas and heavy rainfall curtail many economic activities. Fishing in the open seas is considerably curtailed due to stormy weather and rough seas. The heavy rain also interferes with many agricultural practices such as land preparation, fertilizer and pesticide application, and harvesting. Rubber tappers are severely affected since rubber tapping is not possible during the rainy period. Flooding especially in the low-lying areas is fairly frequent, resulting in damage to crops and property, and even loss of human lives. The tourism industry is also heavily affected, with the lowest hotel occupancy rate registered during this period.

2.2.2 Tropical cyclones

Tropical cyclones are violent whirling storms, several hundred kilometers in diameter that develop over tropical water. They creates strong storm surges with heavy torrential rain that can produce deadly and destructive floods. Whilst the incidence of typhoons in Malaysia is very rare, and their direct attack is almost non-existent, they exert a tail or fringe effect especially in the states of Sabah. The resultant storm and heavy rains trigger floods, damaging property and communications.

2.2.3 Haze

Haze occurs when there is sufficient smoke, dust, moisture and water vapor suspended in the atmosphere to result in reduced visibility and a drop in air quality. Pollutants emitted to the atmosphere are transported hundreds and thousands of kilometers, based on wind direction and weather conditions. Prolonged dry weather, stable atmosphere and high concentration of air pollutants enhance the formation of haze. Particulates emitted into the atmosphere are trapped within the stagnant air masses causing the particulate concentration to increase, thus producing a hazy condition. In Peninsular Malaysia, haze is most likely to occur during the months of January to February and June to August, associated with the drier months. The main sources of pollutants are the exhaust from motor vehicles, emissions from factories, and open burning of municipal waste, with the biggest source of all being the large scale burning of forest and plantations for land clearing. Since the incidence of haze is closely linked to climate variability (especially drought), it will be discussed further in a later part of the report.

2.2.4 Thunderstorms and squall lines

Thunderstorms are another common phenomenon occurring all year round usually during the afternoon and early evening. They are manifest by lightning and thunder and usually followed by heavy rain. Hence rain from thunderstorms can lead to flash floods and landslides. Squall lines, on the other hand, is a term used to describe moving lines of thunderstorms. They generate gusty winds and heavy rains which are more intense and extensive than individual thunderstorms. Squall lines usually occur during pre-dawn and early morning, and are most frequent between the months of April and November.

2.3 The El Nino

For many decades, the Malaysian climate has been fairly stable and predictable. However, for the last twenty years, there was a more frequent and rampant abnormal climate variation. This was brought up predominantly by El Nino induced weather variability, which brought serious implications on all economic sectors, including that of agriculture and the rural economy. The subsequent write-up will describe the El Nino event in Malaysia, its effect in terms of drought occurrence and haze formation, and finally a brief insight on its impact on selected sectors of the economy.

2.3.1 El Nino Southern Oscillation

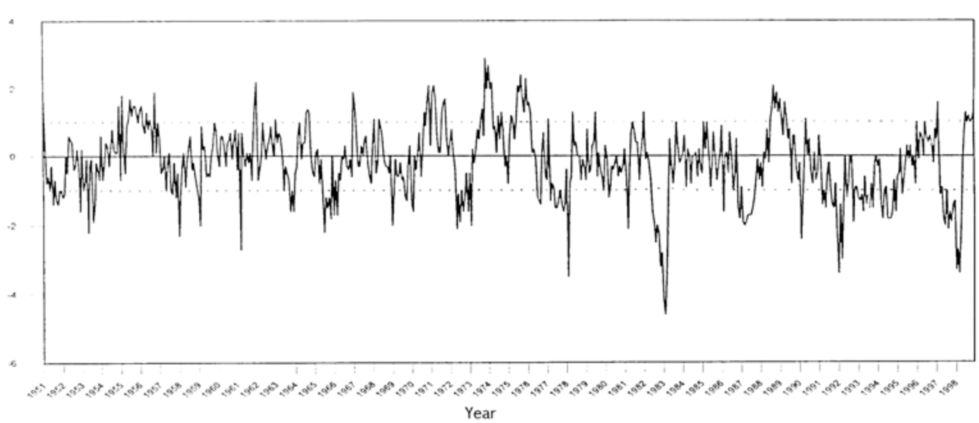
The term El Nino refers to the extensive warming of the entire equatorial zone of the central and eastern Pacific Ocean, which leads to a major shift in atmospheric circulation. This changes the weather pattern worldwide, especially across the Pacific. This is 'abnormal' since under the normal situation the surface ocean in the central and eastern equatorial Pacific is colder than that in the western equatorial Pacific. Such episodes occur at regular intervals of 2 to 7 years. Due to its appearance around the Christmas season, the local resident along the coasts of Ecuador and Peru referred to this abnormal seasonal warming as 'El Nino', which means 'The child'. The term ‘El Nino’ is now synonymous to describe this ‘warm’ episode.

Scientists believe that this phenomenon is closely related to a global oscillation known as the Southern Oscillation (SO). This Southern Oscillation is actually the balancing act of the east-west air masses between the eastern and the western halves of the Pacific. Normally, a persistent high-pressure zone dominates the atmosphere above the eastern South Pacific, while a low-pressure zone dominates the west (Kimberly 1995). The two systems are coupled: when the pressure rises in the east, it falls in the west and vice versa.

Under normal weather conditions, this difference in pressure drives the trade winds from the east to west along the equator. However, during the El Nino years, the reverse occurs. During this period, the South Oscillation Index (SOI), which is a term used to describe the differences in air pressure between Easter Island, Tahiti and Darwin, Australia drops sharply. The subsequent formation of abnormally warm waters in the equatorial central and eastern Pacific gives rise to cloud formation and heavy precipitation in the region. On the other hand, abnormally drier conditions prevail in the western Pacific, affecting countries in the South East Asia and Northern Australia. This combination of El Nino, which is the oceanic component, with the Southern Oscillation, which is the atmospheric component, gives rise to the term El Nino Southern Oscillation (ENSO). As a general rule, the El Nino event occurs when there is a significant and sustained negative SOI for at least 6 months, it is La-Nina when the SOI is positive for at least 6 months. The index for the last fifty years is depicted in Figure 2.2.

In contrast to El Nino, La-Nina (literally translated as 'the girl child') refers to colder than normal ocean temperatures across the central and eastern equatorial Pacific. This leads to an enhancement of normal weather patterns across the Pacific, resulting in wetter than normal conditions in Southeast Asia and Australia, while the central equatorial Pacific region experiences drier conditions. The frequency of its occurrence is about half of that of El Nino.

Figure 2.2 Southern Oscillation Index (SOI).



2.3.2 El Nino events in Malaysia

Since 1950, there were twelve major El Nino events recorded in the country. During the same period, seven La-Nina events were also recorded. These so called El Nino years and La-Nino years are shown in Table 2.4.

The worst El Nino event affecting the country was the 1997/98 event, which began in March 1997 and continued until June 1998. This was followed by the La-Nina of 1998/99. The previous major event was the El Nino of 1982/83. These two episodes, and the 1990 episode, represent major El Nino episodes. Climatic changes during these episodes (denoted as El Nino years) will be extensively used in the subsequent analysis in this report. Overall, the immediate effect of all El Nino episodes was the delay in the monsoon rains, which resulted in abnormally dry weather for most parts of the country. 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 deliberately by plantation firms and timber companies to clear land, since this was considered the cheapest and the most practical method for land preparation. The practice of shifting cultivation by small farmers aggravated the problem further. The resultant pollutants produced a far greater impact with respect to severe deterioration in air quality, which was more detrimental than that of drought alone.

Table 2.4 Major episodes of El Nino and La-Nina affecting Malaysia.

El Nino Years	La-Nina Years
1951/52	1950/51
1953/54	1955/56
1957/58	1970/71
1965/66	1973/74
1969/70	1975/76
1972/73	1988/89
1977/78	1998/99
1982/83	
1986/87	
1991/92	
1994/95	
1997/98	

Source: Lim and Ooi (1998b).

2.3.2.1 Impact on rainfall

The impact of the previous El Nino episodes in terms of less than normal rainfall was 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 drought is fairly common. However, in the recent El Nino, the impact was felt throughout the country.

Tables 2.5a and 2.5b indicate the variations of the standardized northeast and southwest rainfall departure during the period 1968 - 1998. When the SOI is significantly negative, as is very obvious in all the El Nino years, the rainfall deficit is fairly significant, which leads to dry periods during the year. The comparison in terms of mean monthly rainfall and rainy days between ‘normal years’ and major El Nino years is shown in Figure 2.3.

The variation in annual rainfall during the two periods is significant, ranging between 152 mm in the West Coast region to 558 mm in Sarawak. The exception is for the Northwest region, where the difference in rainfall is marginal, at only 14 mm per year. A similar trend is observed for the number of rainy days in a year, where the difference ranges from 2.4 days in the Northwest region to 24 days in Sabah.

A similar comparison with the El Nino episode of 1997/98 is shown in Figure 2.4. It denotes the variation in rainfall and the number of rainy days between these two periods for the regions in the country. The reduction in rainfall is fairly significant for all regions, ranging from about 100 mm in the Northwest region to almost 1100 mm in Sarawak, an equivalent rainfall reduction of 5% to 26% respectively. Similarly, the number of rainy days showed a significant reduction for all regions, ranging between 13 days in Central Interior region and 51 days in Sabah, a reduction of 8% to 28% respectively. This confirms the fact that the El Nino episode of 1997/98 was the worst.

Apparently, it seems that the Northwest region was the least affected in terms of total rainfall during the previous El Nino year, yet the level of rainfall for the period was among the lowest for all regions at 1800 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. Since this is 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.

Table 2.5a Relationship of SOI and Standardized Southwest Monsoon Rainfall Deviation.

Period	SOI				Standardized Rainfall Departure											
					East Malaysia				Peninsular Malaysia							
									East Coast				West Coast			
	May	June	July	August	May	June	July	August	May	June	July	August	May	June	July	August
1968	1.1	0.9	0.6	-0.1	-0.07	-0.10	0.23	0.62	1.59	0.01	-0.89	0.35	0.14	0.12	0.24	0.55
1969	-0.6	-0.2	-0.7	-0.6	2.43	-0.87	-0.06	1.70	-1.00	-0.27	0.11	-0.11	0.70	1.18	-0.65	2.08
1970	0.1	0.7	-0.6	0.2	1.30	1.14	-0.99	0.49	-0.61	0.72	0.31	-0.09	1.07	-0.16	1.18	-0.24
1971	0.7	0.1	0.1	1.3	0.51	-0.33	-0.95	1.68	0.32	-1.16	0.98	-0.08	-0.64	0.63	-1.32	1.08
1972	-2.1	-1.1	-1.9	-1.0	-0.91	-0.73	0.06	-0.88	-0.30	-0.43	0.25	0.14	-1.82	-0.14	-2.12	-1.10
1973	0.2	0.8	0.5	1.1	0.36	1.41	0.86	-0.43	-1.48	1.18	0.50	-0.27	2.43	0.59	0.01	0.38
1974	0.9	0.1	1.2	0.5	-0.95	0.33	-1.31	-0.57	-0.78	-0.17	1.07	-0.34	-0.08	0.03	-0.93	-0.31
1975	0.5	1.1	2.1	1.9	-0.59	-0.11	0.27	0.20	0.78	1.90	-1.35	0.24	-0.30	-0.62	1.19	-1.07
1976	0.2	0.1	-1.2	-1.3	-0.27	-0.53	-0.42	0.63	1.58	0.42	1.60	0.14	-0.93	-0.16	0.48	0.55
1977	-0.9	-1.5	-1.5	-1.3	-2.04	0.19	-0.46	-0.23	1.00	-0.82	0.11	0.47	0.20	1.48	-1.53	0.87
1978	1.3	0.3	0.4	0.0	1.57	0.11	-1.06	-1.02	-0.14	1.23	-1.12	-0.03	0.31	0.06	0.06	0.42
1979	0.3	0.4	1.3	-0.6	-1.99	3.57	1.92	-0.98	-1.13	0.44	-0.15	-0.28	-2.40	2.05	1.19	-0.54
1980	-0.3	-0.4	-0.2	0.0	-0.02	1.00	-0.29	1.82	-0.05	1.00	0.36	0.05	1.30	-0.10	0.06	1.28
1981	0.7	1.0	0.8	0.4	-0.94	-0.88	1.13	-1.90	-0.85	-1.98	-1.38	-0.51	0.19	-1.40	-0.54	-2.02
1982	-0.7	-1.6	-1.9	-2.5	1.14	-1.63	-1.37	-0.91	-0.03	0.45	1.41	0.32	1.26	-1.17	1.33	-0.85
1983	0.5	0.3	-0.8	-0.2	0.34	0.77	0.32	1.02	-1.02	0.62	0.76	0.06	0.57	-0.34	0.87	0.92
1984	0.0	0.8	0.0	0.0	1.73	-0.43	2.16	-0.80	0.04	1.09	0.90	-0.05	-0.88	-0.34	1.41	-1.52
1985	0.2	-0.9	-0.3	0.7	0.64	-1.64	-0.37	-0.13	1.23	-1.90	0.01	0.32	-0.45	-2.15	-1.34	0.79
1986	-0.5	0.7	0.1	-1.0	-1.09	0.26	0.28	-0.06	-0.07	-0.96	-1.80	-0.34	0.61	-0.78	-0.64	-0.95
1987	-1.7	-1.7	-1.7	-1.5	0.46	0.12	-0.01	-0.25	-1.37	1.51	-1.16	0.02	0.87	-0.27	-0.64	0.27
1988	0.8	-0.2	1.1	1.4	-0.18	-0.75	1.64	1.61	1.12	-0.69	-0.81	-0.06	-0.65	1.86	0.67	1.49
1989	1.2	0.5	0.8	-0.8	0.46	-0.59	-0.46	0.00	0.50	-0.78	0.13	0.28	-1.39	0.97	-0.54	-0.05
1990	1.1	0.0	0.5	0.5	0.31	-0.25	-0.34	-1.47	-0.07	-1.02	1.03	-0.45	-0.45	-1.40	-0.07	-1.34
1991	-1.5	-0.5	-0.2	-0.9	-0.58	0.09	-1.01	-0.02	1.06	-0.77	-2.04	-0.06	3.59	-0.48	0.81	0.17
1992	0.0	1.2	-0.8	0.0	1.24	-0.33	-0.61	0.06	-0.51	0.56	-0.10	0.01	0.75	-1.18	0.43	-0.48
1993	0.6	-1.4	-1.1	-1.5	-0.22	-1.80	2.78	-0.12	-1.29	-0.02	-0.69	0.27	1.04	0.51	1.49	-0.09
1994	-1.0	-0.9	-1.8	-1.8	1.13	2.04	-1.64	2.11	1.95	0.80	-0.71	-0.06	0.66	-0.15	-1.57	0.00
1995	-0.7	-0.2	0.3	-0.1	0.31	-0.20	1.08	3.26	-0.24	0.96	1.34	0.40	0.02	0.87	-0.26	1.99
1996	0.0	1.0	0.6	0.4	0.72	0.68	-0.79	0.31	-1.22	-0.53	-0.06	0.31	-0.53	0.02	0.61	2.14
1997	-1.8	-2.0	-1.0	-2.1	-0.50	-1.44	0.26	-1.32	-1.74	-1.27	-2.11	-0.16	-1.97	-0.89	-0.52	-0.34
1998	0.1	0.7	1.3	1.0	-1.22	-0.06	0.27	2.54	-0.67	0.72	-0.28	0.03	1.27	-0.11	0.99	2.83

NOTE: Standardized Rainfall Departure = $\frac{\text{Total Monthly Rainfall - Total Monthly Mean (1961-1990)}}{\text{Standard Deviation (1961-1990)}}$

El Nino Year

East Malaysia: Kuching, Miri, Bintulu, Kota Kinabalu and Sandakan
East Coast: Kota Bharu, Kuala Terengganu, Mersing and Kuantan
West Coast: Alor Setar, Bayan Lepas, Ipoh, Subang and Melaka

Source: Lim and Ooi (1998).

Table 2.5b Relationship of SOI and Standardized Northeast Monsoon Rainfall Deviation.

Period	SOI					Standardized Rainfall Departure														
											Peninsular Malaysia									
						East Malaysia					East Coast					West Coast				
	Nov.	Dec.	Jan.	Feb.	Mar.	Nov.	Dec.	Jan.	Feb.	Mar.	Nov.	Dec.	Jan.	Feb.	Mar.	Nov.	Dec.	Jan.	Feb.	Mar.
1968/69	-0.5	0.0	-2.0	-1.1	-0.1	-0.69	0.03	-1.16	-0.69	-0.04	-0.76	0.91	-0.26	0.12	-0.81	-1.88	-0.03	2.96	0.11	0.78
1969/70	-0.2	0.3	-1.4	-1.6	0.0	2.13	0.92	-0.15	-0.38	-0.58	1.54	-0.59	-0.34	-0.87	-0.26	0.74	0.65	3.64	-0.63	0.36
1970/71	1.7	2.1	0.3	1.9	2.1	-0.10	-0.81	0.83	1.72	-0.89	-0.51	0.50	1.46	0.19	0.39	-0.07	0.19	2.43	1.07	-0.11
1971/72	0.5	0.0	0.4	0.8	0.1	0.73	0.51	0.21	-0.18	-0.48	0.14	1.02	-0.82	-0.60	-1.04	-1.54	2.18	-0.02	0.35	-2.19
1972/73	-0.5	-1.6	-0.5	-2.0	0.2	-0.66	-1.23	-1.35	-0.80	0.26	-1.15	0.73	-0.04	-0.43	1.59	0.57	0.62	1.65	-0.16	-0.73
1973/74	2.9	2.0	2.7	2.0	2.2	-0.05	2.76	-0.54	1.14	-1.12	0.43	2.03	-1.03	0.61	0.11	0.45	1.10	0.88	-0.53	-1.52
1974/75	-0.3	0.0	-0.8	0.6	1.2	-0.45	-0.76	-0.26	0.19	0.09	0.21	-0.77	1.93	0.76	0.36	1.10	-0.02	2.32	1.34	-0.66
1975/76	1.3	2.3	1.5	1.6	1.3	0.19	1.09	1.06	-0.35	-0.46	1.25	-0.02	-1.07	-1.22	-0.45	-0.21	1.19	1.12	-1.29	0.75
1976/77	0.7	-0.6	-0.7	1.1	-1.3	-1.22	-0.33	0.14	3.54	1.56	1.38	0.36	-0.80	0.78	-0.88	-0.78	-0.09	1.00	0.54	-1.92
1977/78	-1.6	-1.4	-0.4	-3.5	-0.8	-0.60	0.10	-0.21	-0.77	0.14	0.06	-1.01	0.03	0.36	-0.43	-0.21	-1.36	1.66	-0.77	0.22
1978/79	-0.1	-0.3	-0.7	0.8	-0.5	0.17	-0.23	-0.88	-0.8	-0.42	-0.40	-1.12	-0.63	-0.07	-0.28	-1.68	-1.33	-0.03	0.47	-0.63
1979/80	-0.6	-1.0	0.3	0.0	-1.2	1.40	-0.86	0.66	-0.72	-1.3	1.67	-1.70	-0.35	-0.68	-0.72	0.53	-1.78	0.69	0.06	0.66
1980/81	-0.5	-0.3	0.2	-0.6	-2.1	0.41	1.81	0.82	-0.10	-0.31	-0.43	0.28	-0.71	0.03	-0.94	0.18	-0.44	1.05	1.48	-0.93
1981/82	0.1	0.5	1.3	-0.1	0.1	0.80	-0.68	-0.08	-0.18	-0.75	-0.18	1.17	-0.70	-0.82	-0.37	-0.65	-1.70	-0.41	-0.64	1.05
1982/83	-3.2	-2.8	-4.2	-1.6	-3.4	-2.12	-0.63	-0.38	-1.01	-2.03	-1.45	0.79	-0.60	-1.01	-1.11	1.59	-0.51	0.62	-0.91	-0.15
1983/84	-0.2	-0.1	0.1	0.6	-0.9	1.50	1.21	0.29	1.66	0.12	-0.91	2.12	0.61	1.11	0.46	-1.63	-0.19	2.36	2.33	1.98
1984/85	0.2	-0.4	-0.5	1.0	0.2	-0.20	-0.30	-0.76	-0.54	2.02	-0.49	-0.39	-0.12	0.89	3.28	-0.34	0.86	0.40	1.01	1.67
1985/86	-0.3	0.1	0.9	-1.6	0.0	-0.60	0.14	0.95	-0.39	0.49	-0.82	-0.63	-0.40	-1.17	-0.31	2.08	-0.02	0.97	-0.05	-0.17
1986/87	-1.5	-1.8	-0.9	-1.9	-2.0	0.66	-2.08	-0.92	-1.43	-1.53	2.07	-0.98	0.53	-1.15	-0.25	-0.74	-0.37	0.63	-1.24	0.04
1987/88	-0.1	-0.7	-0.2	-0.9	0.1	0.01	1.29	-0.71	0.04	1.14	-1.06	1.20	-0.49	0.08	1.94	0.31	0.87	2.33	1.92	1.12
1988/89	1.9	1.3	1.7	1.1	0.6	2.00	1.21	0.24	0.25	-0.16	2.26	-1.03	-0.42	-0.89	-0.60	0.75	-1.09	1.46	-1.13	0.30
1989/90	-0.4	-0.7	-0.2	-2.4	-1.2	-0.35	-1.09	-0.47	-0.92	-1.37	-0.81	-1.69	-0.08	-0.02	-0.43	-1.23	-0.20	0.93	-0.75	-0.46
1990/91	-0.7	-0.5	0.6	-0.1	-1.4	-0.62	-1.06	-0.66	-0.26	-1.67	-0.74	-1.00	0.53	-0.10	-0.37	-0.21	-0.57	1.28	-0.31	-0.08
1991/92	-0.8	-2.3	-3.4	-1.4	-3.0	-0.80	-0.04	-0.64	-1.08	-1.79	0.44	0.77	-0.24	-0.80	-0.89	-0.80	0.80	0.44	1.23	-0.71
1992/93	-0.9	-0.9	-1.2	-1.3	-1.1	-0.46	0.01	-0.76	-0.89	0.84	0.66	-0.80	0.48	-0.71	1.07	-0.72	1.49	1.28	-0.44	0.70
1993/94	-0.2	0.0	-0.3	-0.1	-1.4	-0.88	1.14	-0.18	-0.57	4.10	-0.08	0.36	-0.50	-0.59	3.61	0.51	1.02	0.72	0.41	2.09
1994/95	-0.7	-1.6	-0.6	-0.5	0.2	-0.36	-0.14	-1.00	0.16	1.15	2.89	-1.01	0.55	0.78	-0.47	0.85	-0.79	1.94	0.27	0.43
1995/96	0	-0.8	1.0	-0.1	0.7	0.27	0.35	0.62	1.57	-0.34	1.43	0.36	0.13	0.45	-0.27	0.14	1.18	1.62	-0.33	0.19
1996/97	-0.2	0.8	0.5	1.6	-1.1	-0.32	0.53	-0.60	1.12	-1.97	-0.59	0.28	-1.15	1.39	-1.07	-1.20	0.60	0.83	0.62	-1.20
1997/98	-1.4	-1.3	-3.3	-2.7	-3.4	-0.70	-1.40	-1.19	-1.36			0.35	0.01	-1.20	-0.58	0.91	-0.08	1.19	0.00	-1.36

NOTE: Standardized Rainfall Departure = $\frac{\text{Total Monthly Rainfall - Total Monthly Mean (1961-1990)}}{\text{Standard Deviation (1961-1990)}}$

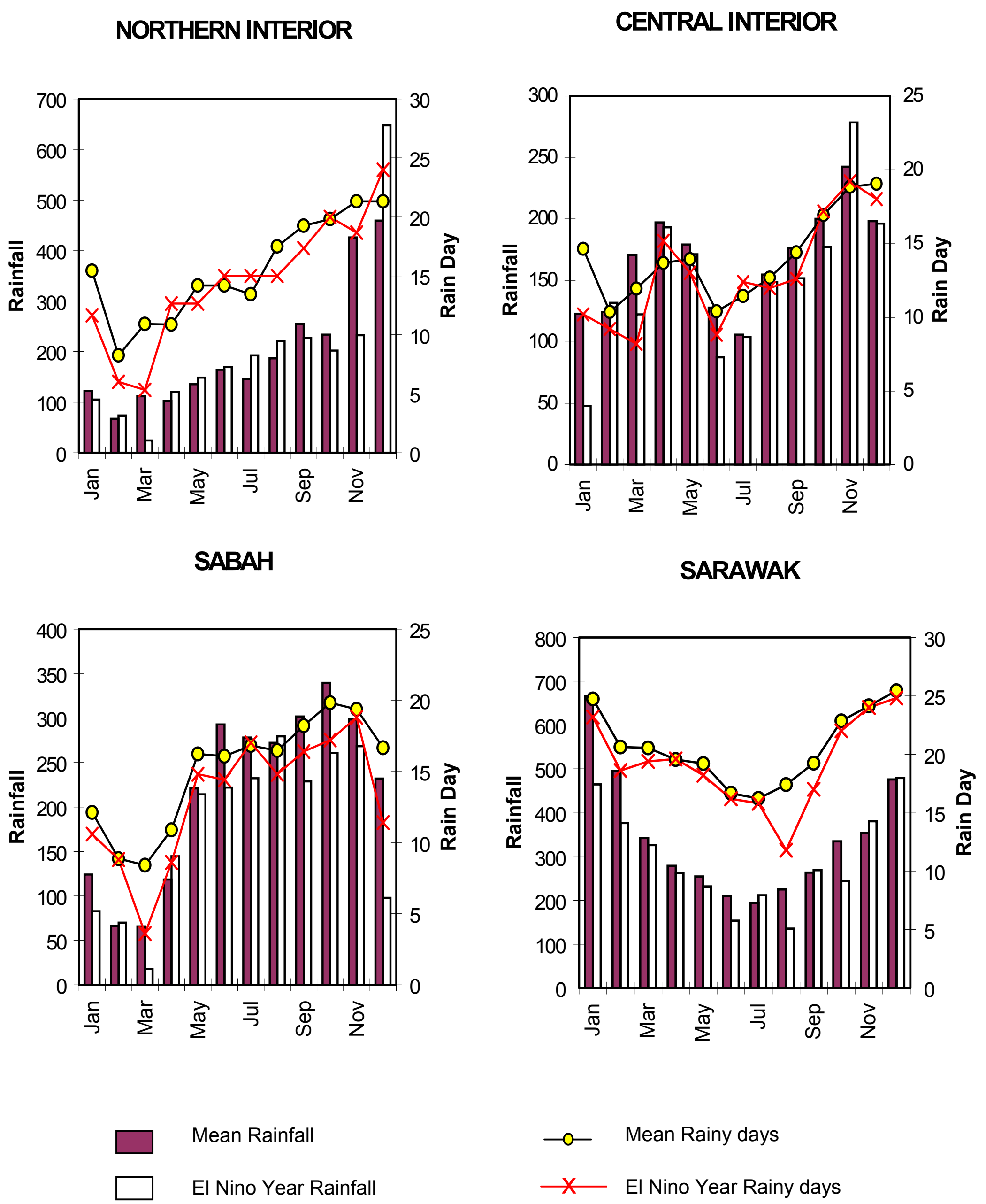
El Nino Year

East Malaysia: Kuching, Miri, Bintulu, Kota Kinabalu and Sandakan
East Coast: Kota Bharu, Kuala Terengganu, Mersing and Kuantan
West Coast: Alor Setar, Bayan Lepas, Ipoh, Subang and Melaka

Source: Lim, J.T. Ooi, S.H. (1999).

Figure 2.3 Malaysia – monthly rainfall and rainy days (mean and El Nino years).

Figure 2.3 Malaysia – monthly rainfall and rainy days (mean and El Nino years), continued.



2.3.2.2 Impact on air quality

As mentioned previously, the El Nino induced climate variability had resulted in prolonged dry weather throughout the country, as well as in neighboring countries. This induced widespread forest and peat swamp fires, which could not be controlled successfully especially in Sumatra and Kalimantan, Indonesia. With the prevailing winds, the smoke particles were transferred toward Malaysia, resulting in heavy haze conditions. 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. At that time, a slight haze was observed in the northwestern region of Peninsular Malaysia, in the states of Kedah and Penang as well as areas near Kuala Lumpur (Lim and Ooi 1998). Soon after, the haze spread to other states including Sabah and Sarawak. By September, almost all parts of the country were affected by haze, with the Total Suspended Particulates (TSP) registered at more than 100 μ/m^3, as compared to the long term mean of 30 - 60 μ/m^3. The worst hit area was Kuching, the state capital of Sarawak, where in the middle of September, TSP values shot up to 839 μ/m^3, which led to the declaration of a national disaster. The highest value recorded was 23 and 24 September 1997 when TSP values for Kuching reached 1032.0 and 1033.0 μ/m^3 respectively (Lim and Ooi 1998). Schools and businesses were closed for days, and residents were requested to stay indoors. The haze level finally subsided in early October 1997. It reemerged in January 1998 but was confined only to the states of Sabah and Sarawak until April 1998 when it ended (Lim 1998). During the peak haze period, satellite images showed many 'hot spots' over Sumatra and Kalimantan, which indicated forest fires in these areas.

Based on readings from selected weather stations, Figure 2.5 indicates the deterioration of monthly air quality in terms of TSP for all regions in the country. The drop in air quality was due to a significant increase in TSP had reached an alarming level in almost all regions. Readings for the Northern Interior and Central Interior were not available, possibly since these two regions had limited economic activities. The exception was for the northwest region, where the mean monthly TSP did not exceed 100, even though there were days when the reading exceeded the value of 100. Yet this represents an almost two-fold increase over the 'normal periods' especially during the peak haze period between the months of July to October 1997. Since the level of TSP is highly related to daily visibility, the effect of the drop in air quality cuts across all sectors.

For all other regions, the increased in TSP during the peak 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.

2.3.2.3 Impact on mean daily temperature

The overall increase in the mean daily temperature between the ‘normal’ (based on 50-years data) and El Nino years was between 0.2^{o}C and 1.1^{o}C for all regions (Figure 2.6). However, during the El Nino period of 1997/98, the mean daily temperature increased further in all regions (Figure 2.7), as compared to the 'normal' years. The variations in temperature for all regions ranged from 0.5^{o}C in Central Interior region to 1.7^{o}C in the southern region. This could be due to the general trend in global warming, where the annual 24-hour mean for all parts in Malaysia showed a similar trend, at the rate of about 1.7^{o}C for every 100 years (Chong and Chan 1994). However, the much greater increase in temperature in relation to that finding could be due to the prolonged dry weather, coupled with the thick haze. An examination by Lim and Ooi (1998) during the normal and hazy days revealed that the temperature in the layer between 700 and 600 hPa (which is the approximate height of the haze) underwent stronger diurnal variations during the haze days as compared to the normal days reflecting the results of radiational heating during the day and radiational cooling during the night in the vicinity of the haze top.

Figure 2.5 Total suspended particulates (ug/m^3) between regions: mean and haze period (July – Dec 1997).

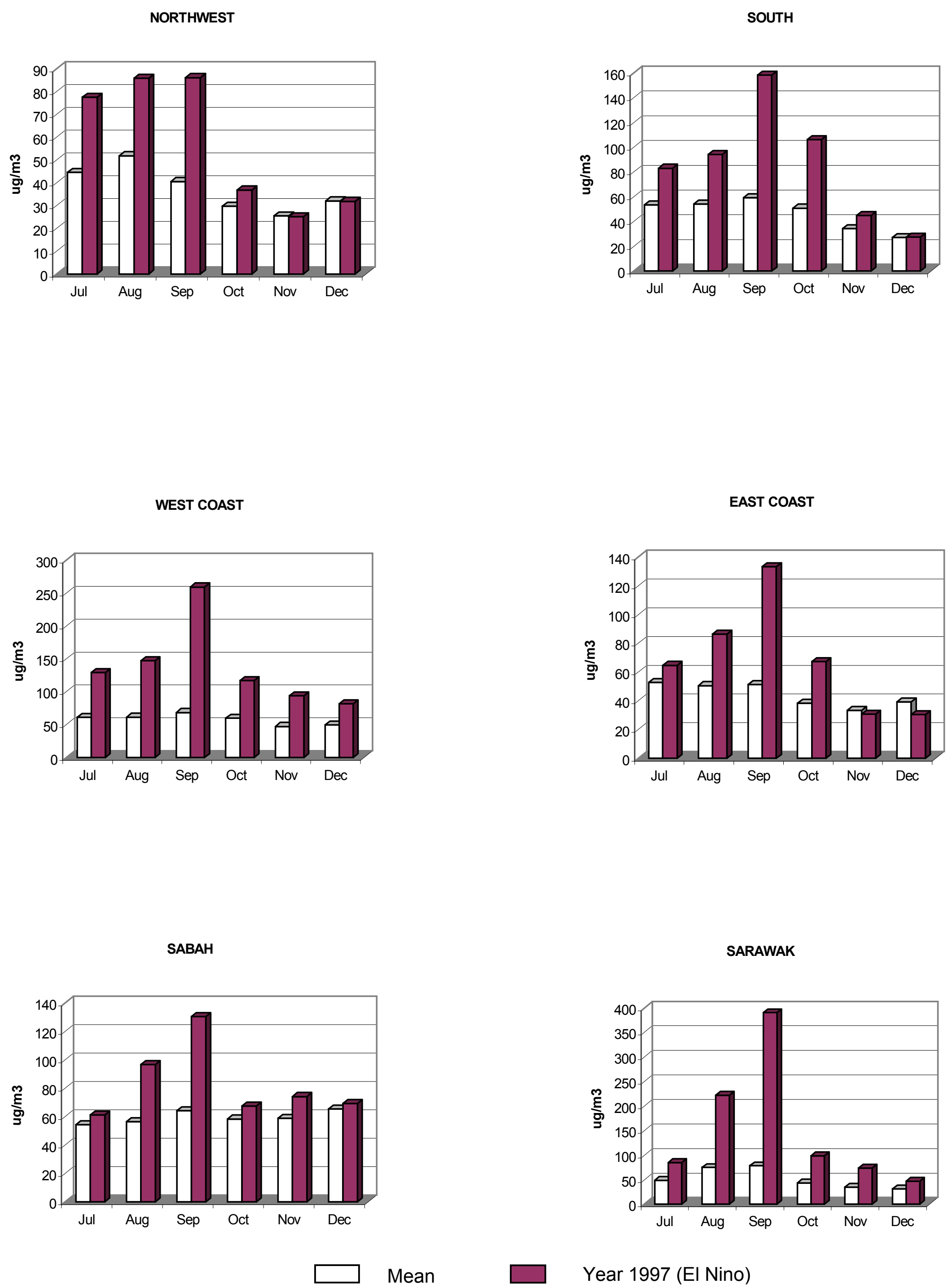


Figure 2.6 Malaysia- monthly mean temperature by region (means and El Nino years).

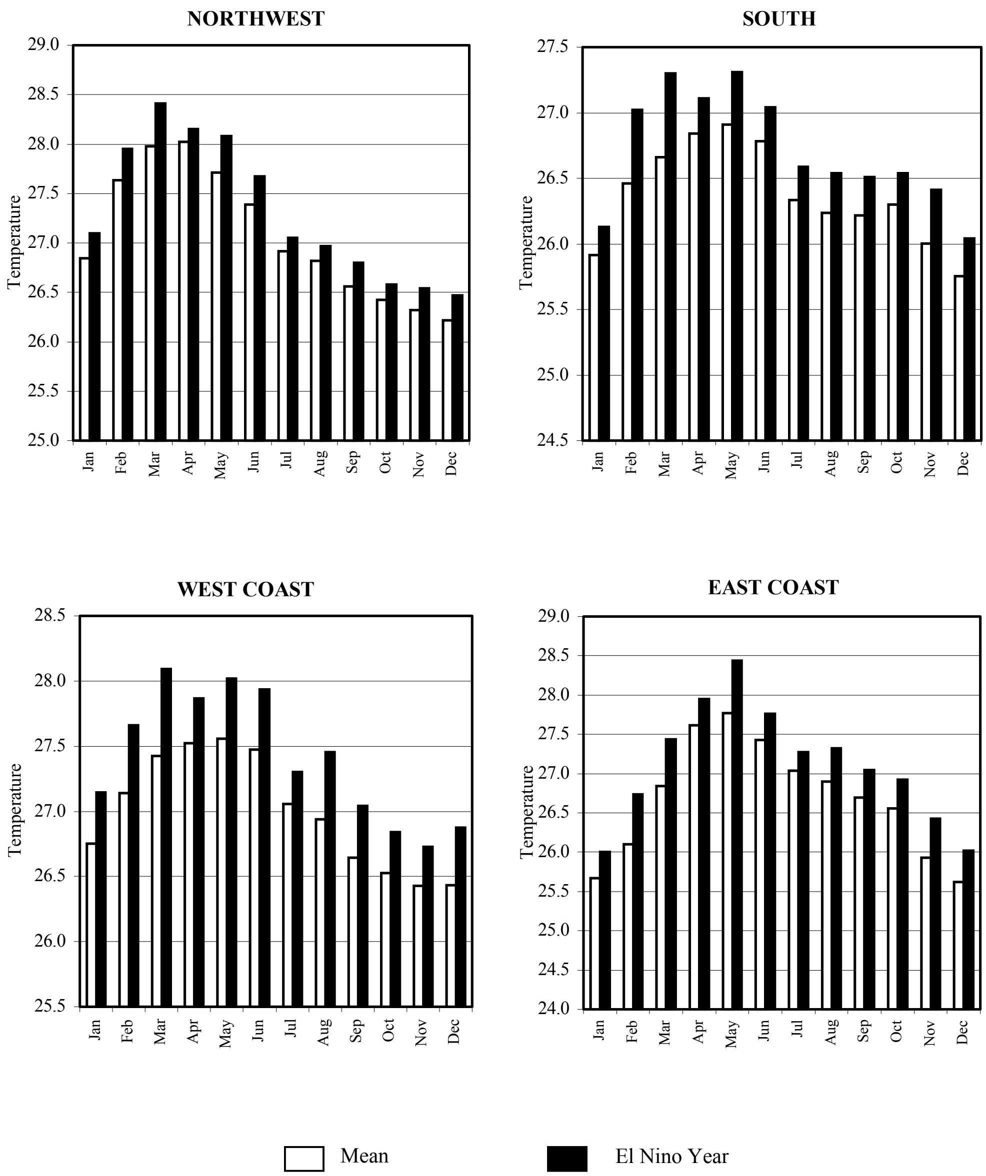


Figure 2.6 Malaysia- monthly mean temperature by region (means and El Nino years), continued.

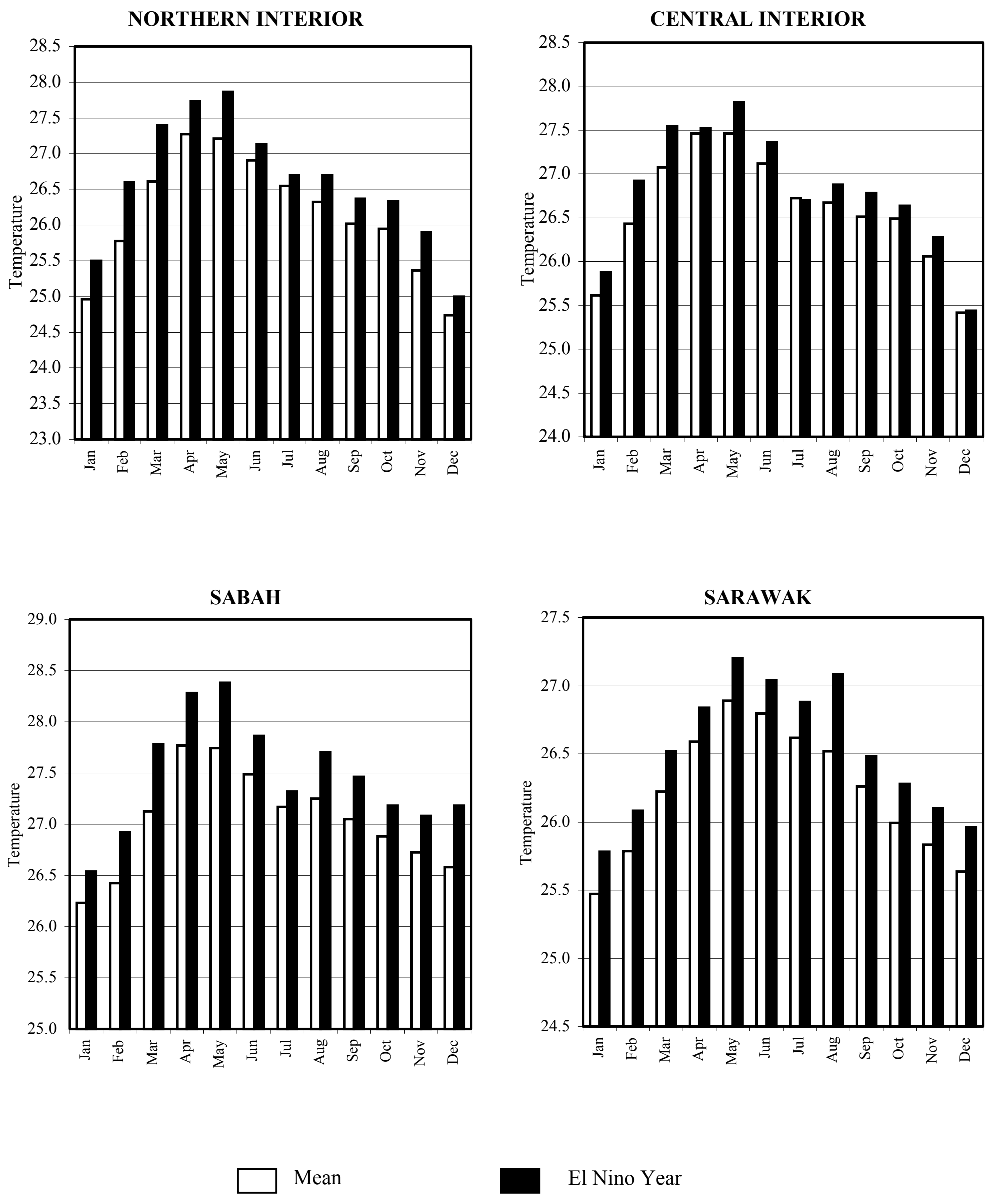


Figure 2.7 Malaysia - monthly mean temperature by region (mean and 1997/98 years).

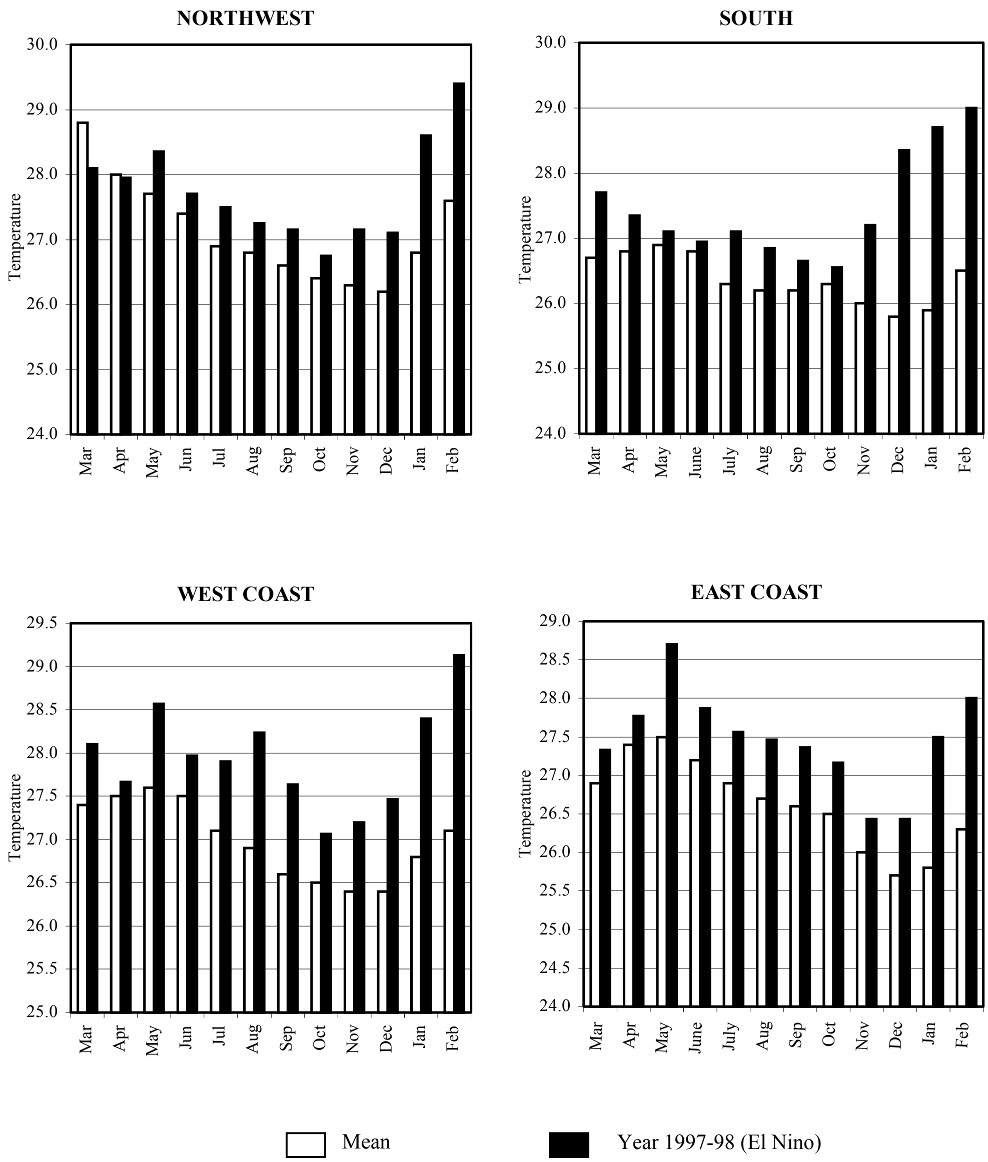
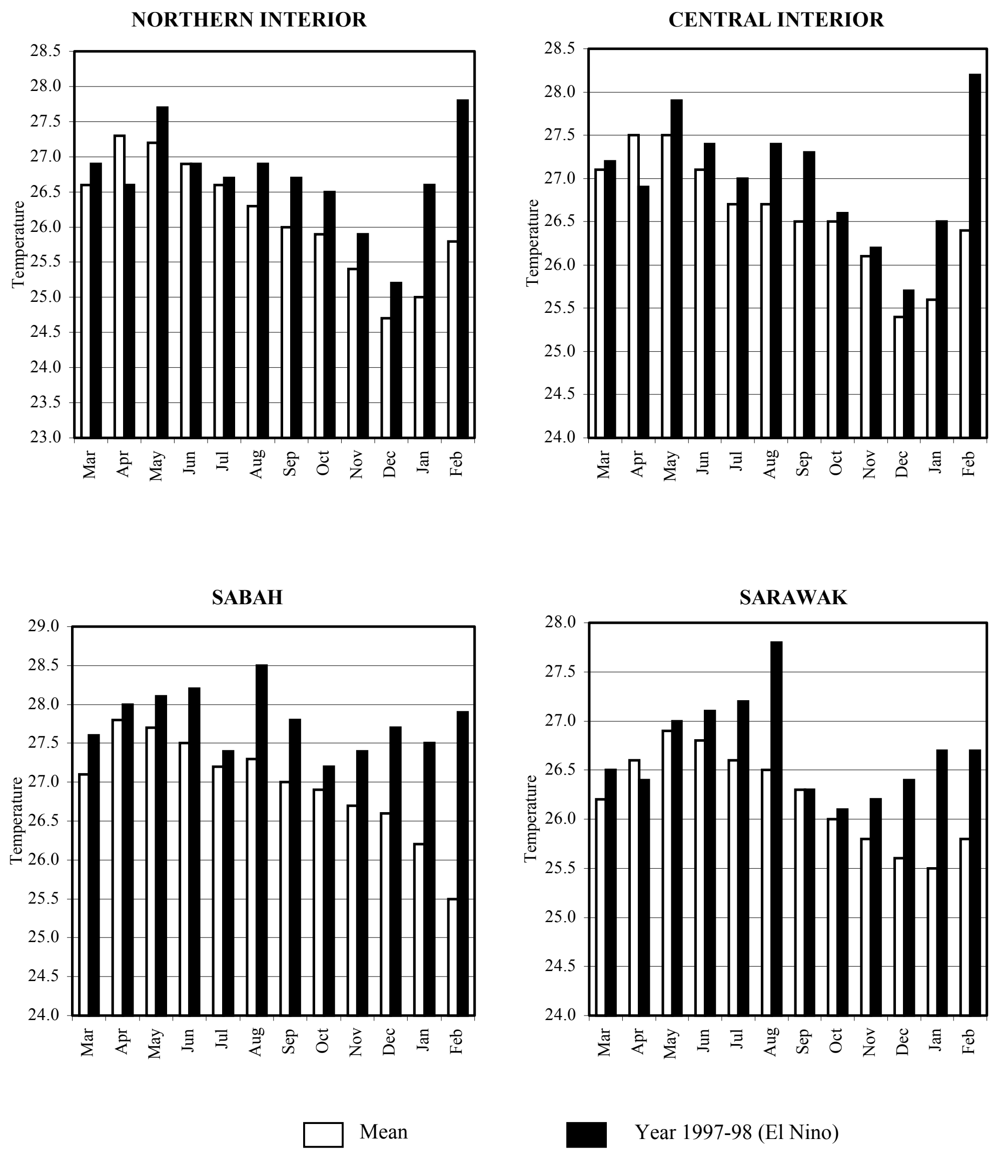


Figure 2.7 Malaysia - monthly mean temperature by region (mean and 1997/98 years), continued.



2.4 General impacts of El Nino induced weather changes in Malaysia – a review

The immediate effect of El Nino in Malaysia is the delaying of the rainy season, which leads to the extension of dry weather. The resultant hot and dry weather leads to acute water shortages. Particularly for the 1997/98 episode, the effect was worse because of the haze resulting from the forest and swamp fires both from domestic sources as well as from neighboring countries.

2.4.1 Drought related impacts

The existing literature on economic losses brought about solely by drought in this country are rather limited. This is especially so with regards to the economic losses incurred by the agricultural sector. There are several possible reasons for this.

Firstly, the drought prone areas in the country are rather limited. The northwest region is the only region in the country where there are distinct dry seasons lasting two to four months in a year. This condition has been fully exploited for the production of mango and sugarcane, which require such climatic conditions. Paddy, which is also important in the region, is planted within the MADA irrigation scheme, which in 'normal' years will not have a problem in providing adequate water for the crops in the dry season.

Rubber, which is the most important primary commodity in the region, being a perennial crop does not require as much water as other commodities. In fact, prolonged dry and hot weather, as is usually the case during the El Nino period, is a 'welcome' phenomenon since it could contribute positively to the rubber tappers. Fewer rainy days means more tapping days for them. Similarly, the sugar plantations respond positively to long dry spells as they could increase the sugar content of the sugarcane, as long as water is available during the establishment and growing period.

The more significant effect of drought would be on the household front. Prolonged drought brought about by El Nino, as was the case during the El Nino of 1982/83 and the more recent one in 1997/98, resulted in a serious decline of water levels at the dams, to almost critical levels. This resulted in a very serious water crisis especially within the federal capital, Kuala Lumpur and its surrounding vicinity. The very low rainfall during the El Nino of 1997/98 resulted in water rationing for 1.2 million people in the area. This created many inconveniences for the people and disrupted many economic activities. At the peak of the drought period, the residents of Kuala Lumpur were given rationed water supply on alternate days. For some parts of the city, water was distributed by a large fleet of water tankers. Even those arrangements were not sufficient to fulfill the water need of the population. Other parts of the country had not faced similar acute problems, even though some rationing had also been imposed especially in major cities.

Concerning the health aspect, numerous cases of vector-borne disease outbreaks associated with anomalies were reported to accompany the 1997/98 El Nino event (Epstein 1999). Drought induced famine, which was aggravated by poverty and poor sanitation, increased the vulnerability to diarrhea and cholera, especially in Indonesia, Malaysia and the Philippines. The prolonged dry weather and drought resulted in the lack of clean drinking water especially in the rural areas. The drying up of rivers and streams enabled mosquitoes to survive at high altitudes, with the resultant increase in the outbreak of malaria (Epstein 1999), particularly in Irian Jaya and Papua New Guinea, India, Thailand and Philippines. Similar conditions enhanced the upsurge of dengue fever in Malaysia, Thailand and Indonesia.

2.4.2 Haze related effects

The spin-off effect of prolonged hot and dry weather is the haze problem. It was estimated that the dry weather triggered widespread forest fires estimated to have claimed 1.5 to 2.0 million acres of forest on the islands of Sumatra and Borneo. The other source of fires came from the clearing of land for agricultural purposes, both by big corporations and small farmers, since burning is claimed to be the most efficient and practical way to clear land for crop cultivation. Persistent southeasterly wind brought smoke particulates to the country, spreading the widespread haze to the whole nation.

The estimate for haze related damage in selected sectors in Malaysia in terms of the economic losses brought about by the El Nino of 1997/98 was US$ 210 million. While this is most likely an underestimate, this amount by comparison is sufficient to finance all of the federal government's social programs for three years (Mohd Shahwahid et al. 1998). According to the Worldwide Fund for Nature, the smoky haze caused by forest fires, drought and wind, incurred an estimated loss of up to US$ 6 billion world-wide. This included both the direct cost such as loss from agricultural output, and the indirect cost through medical bills and a reduction in tourism industry. An estimate by EEPSEA (1998) of the total economic loss in the three most affected countries in Asean was US$ 1.38 billion, in which US$ 310 million was incurred in Malaysia, US$ 63 million in Singapore, and US$ 1,012 million in Indonesia. The loss in Malaysia included both the economic damage and the abatement costs, such as fire fighting, monitoring and enforcement activities.

The severe haze, brought about by El Nino weather change, triggered many studies. In particular, there were concerns and interests by the government and researchers on the possible impact of the haze across economic sectors. The economic sectors badly affected by the severe haze episode were the tourism industry (including the hotel industry), the aviation and transportation (especially shipping) industries and agricultural industry. In fact, it is fairly reasonable to say that it cuts across all sectors, either directly or indirectly, due to its hazardous nature to humans. Reviews on some of these findings are presented below. Special attention is given to the haze episode of 1997/98, since this is the worst to hit the country.

Impact on human health

The World Health Organization (1998) concluded that the haze-related air pollution problems, as experienced during the El Nino of 1998/78, represent a substantial health risk to the public. The main component of the haze that adversely affects health is the particulate level, which is associated with a range of adverse, non-cancer health impacts. Whilst the risk of long-term health effects due to a single haze episode is difficult to detect, the short-term effects are fairly obvious. Increased mortality, hospital admissions, emergency room visits and respiratory related problems during the haze episodes represent some of the immediate effects of haze on health (Mazrura 1998). This is the direct impact of haze on health, since it has been established that the excessive emission of suspended particulate is associated with aggravation of respiratory tract infections, asthma, chronic bronchitis, emphysema and conjunctivitis (Mohd Nasir et al. 1998). A report by EEPSEA (1998) indicated a conservative cost estimate of RM 2.1 million for upper respiratory tract admissions during the first fifteen days of September 1997, which was the peak of the haze episode, as compared to RM 1.1 million for the months of July and August for three government hospitals in Kuala Lumpur in the same year. Hence, EEPSEA estimated that the total health damage for the 1997 haze episode was about RM 20.1 million. Mohd Shahwahid et al. (1998) obtained a quantitative health cost by using a dose response function to provide a relationship between how much illness a given dose of haze pollution causes, with subsequent losses in productivity due to illness. The cost was calculated based on the cost of illness in terms of hospital admission, purchase of medicines and related productivity losses. An estimated value of RM 21 million was identified as the adjusted cost of illness arising from the 1997/98 haze episode.

Impact on animal production

There has not been a comprehensive study to evaluate the impact of haze on the health and subsequently the production of livestock in this country. Whilst there are studies which indicated that the haze of 1997/98 did have same adverse effects on animals (Nordin et al. 1998), the economic losses incurred were insignificant. The effect on health and production was also very minimal with a reported drop in the production of chicken at less than 5%. For the pig industry, there were increased cases of respiratory problems, poor growth and abortion, especially during the peak haze period. The estimated economic loss, however, was also very small.

Impact on fishing industries

The effect of haze on aquatic organisms and subsequently the marine and aquaculture industry is due to its ability to reduce light penetration to aquatic organisms. The reduction of light intensity has an adverse effect on aquatic organisms and subsequently on the overall food chain, and the final fish resources. Similarly, 'acidic' precipitation could result in decreased pH of water bodies, hence effecting the survival, reproduction, growth and movements of aquatic organisms (Hishamuddin et al. 1998). This could result in a significant decline in fishery resources and stocks.

Coupled with that, the reduced visibility at sea would discourage fishing activities, especially in the open sea. This resulted in a decline of fish landings during the haze period, which led to an estimated decline in consumer surplus of RM 40.7 million (Mohd Shahwahid et al. 1998). On the assumption that the supply is very inelastic, the estimated welfare loss to society is almost equivalent to that of the decline in consumer surplus. A study conducted to evaluate the impact of haze on shrimp culture estimated a financial loss of RM 117 million in the country, primarily due to lower survival rates and productivity (Fatimah Md. Yusoff 1998).

Impacts on aviation industry

This is derived from the income foregone due to flight cancellations and closure of airport operations. For the period between August 1997 and November 1997, there were 3,278 flight cancellations and 1,049 flight delays due to poor visibility caused by haze (Mohd Nasir et al. 1998). Out of this, the total loss due to flight cancellation alone accounted for RM 19.4 million and another RM 2.4 million due to flight delay. The bulk of the losses were incurred by airports in the states of Sarawak, which accounted for about 80% of the loss. Poor visibility from haze may also have been a factor in the crash of a jetliner in Sumatra on September 26 that killed all 234 people aboard, as well as for a series of near fatal collisions. For the year 1997, there were four ship collision accidents in the Straits of Malacca, reportedly due to reduced visibility.

Impact on tourism industry

The impact of haze on the tourism industry is quite obvious. Smoggy, smoke laden air and 'blackish sky' rather than normal 'blue sky' do not attract tourists. Similarly, heavy haze disrupted air travel, forcing cancellation of flights, closure of airports and diversion of aircraft due to their inability to land because of poor visibility. During the period, the hotel industry suffered heavy losses from both the low hotel occupancy rates as well as the poor food and beverage earnings. At the peak of the haze incidence, the average room occupancy of five star hotels in Kuala Lumpur plunged to as low as 30%, against the normal 80 to 90% during the usually busy month of October. Similar losses were expected by other tourism-related industries. Whilst the actual loss due to haze alone is rather difficult to assess since the drop could be due to many other factors, including the economic recession which began at almost the same time as the haze period, the economic loss during the period was quite substantial. The tourism receipts, which had contributed RM 11.3 billion in 1996, dropped to RM 10.5 billion in

1997 and RM 9.3 billion in 1998. During the same period, tourist arrivals dropped from 7.1 million in 1996 to 6.2 million and 5.5 million in 1997 and 1998 respectively (Government of Malaysia 1999).

Impact on agriculture industry

Environmental stress, in the form of climate variation does affect crop yields. Among the most important climatic factors that could result in stress to crop growth and hence crop productivity are the rainfall, temperature, sunshine and air quality. Generally, agricultural commodities in the tropics require at least five hours of sunshine a day, sufficient water especially during the growing period, and little variation in temperature regime. Hence, theoretically an El Nino episode, which is associated with prolonged drought and poor air quality, could directly affect the yield. The impact could be immediate or delayed to a later period. For example, the lower oil extraction rate for palm oil in both 1997 and 1998 could be due to the haze incidence during the period. Based on this assumption, Mohd Nasir et al. (1998) postulated that palm oil yield was reduced by 3% in 1997 and 1.1% in 1998, which was equivalent to a loss of about RM 427 million for the two periods. Similarly, the New Straits Times reported a yield reduction of about 10% in rice production due to haze in KETARA (Kelantan Utara Development Authority, a regional land development authority), which is one of the eight rice granary areas in the country (Mohd Nasir 1998). This relationship, in terms of effect and impacts, between the El Nino weather change and agricultural development is the crux of this study. This will be dealt with in greater detail in later chapters of this report.

3. The Malaysian Agricultural Sector

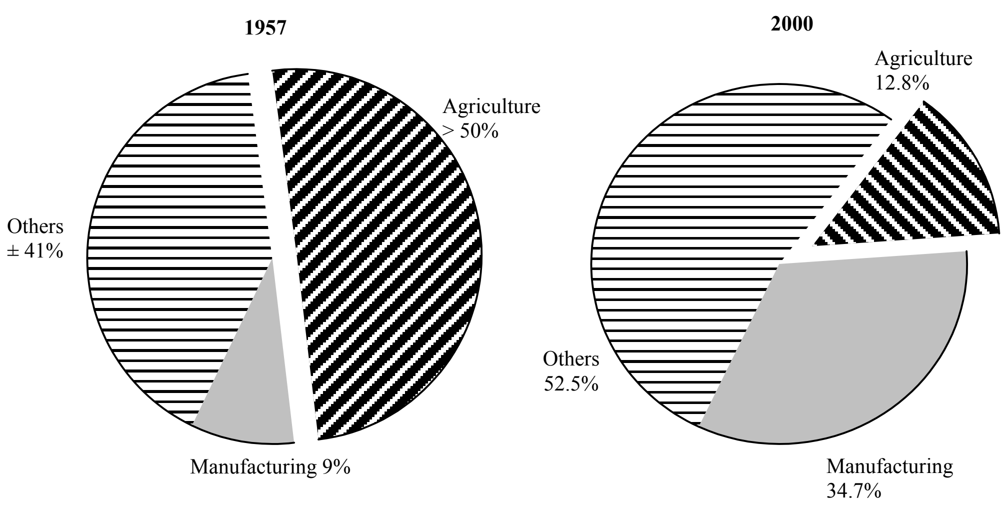
This chapter describes the salient features of the Malaysian agricultural sector. The first section is devoted to describing the development that has thus far taken place from the early days since independence to recent years. The description emphasizes macro-trends in terms of the structural and export composition of the sector and also the importance of the sector to the national economy. The second section highlights some salient policy aspects in agriculture. This includes aspects relating to food security, commercialization, equity distribution and poverty reduction as well as the institutional setting.

Understanding the status and the economic and social importance of the sector in the economy and national development helps to further comprehend the importance a phenomenon like the El Nino can have on the agricultural sector. These effects include the macro-economic aspects and also the micro aspects such as income of farmers.

3.1 Agriculture in the Malaysian economy

The agricultural sector in Malaysia plays a critical role in the economy of the country. During the early days after independence in 1957, the agricultural sector contributed more than 50% of the GDP. The industrialization drive of the 1970s and the expansion of the service sector has led to the declining importance of the agriculture sector in terms of GDP contribution, employment and also export earnings. In 2000, almost 45 years after gaining independence, the structural composition of the Malaysian economy has substantially changed. Agriculture now contributes only 12.8% to the nation's GDP with the manufacturing sector accounting for almost 35% of the total GDP (Figure 3.1)

Figure 3.1 Contribution of agriculture and manufacturing to GDP, 1957 and 2000.



The sector's performance in terms of other major macro economic parameters also exhibited similar trends. In the last two decades agricultural employment has declined from 37.2% to only 16.0% (Table 3.1). In the other sectors, notably, manufacturing, employment has increased from 15.5% to 27.5%, an increase of 12% over the 20-year period (Table 3.1). The percentage share of agricultural products in exports also registered a decline for the period. Its share of exports declined from 48.5% in 1980 to only 6.5% in 2000, a decline of 86.6% during the period (Table 3.2). In short over the last two decades, the contribution of the agricultural sector to the GDP has declined by over 44%, while the declines in share of employment and exports were by 56.7% and 86% respectively.

Table 3.1 Employment by sector (%), Malaysia, 1980 - 2000.

Sector	1980	1990	1995	2000
Agriculture	37.2	26.0	18.0	16.1
Manufacturing	15.5	19.9	25.9	27.5
Mining	1.3	0.6	0.5	0.4
Construction	5.7	6.3	8.3	8.5
Government services	13.3	12.7	11.0	9.9
Other services	27.0	34.5	36.3	37.6
Total	100.0	100.0	100.0	100.0

Sources: Malaysia (1986, 1996, 1999).

Table 3.2 Share (%) of agricultural exports in total exports.

Sector	1980	1990	1995	2000
Agriculture	48.5	22.3	13.1	6.5
Mining	26.4	18.3	5.8	9.6
Manufacturing	206	58.8	19.6	82.8
Others	9.3	0.6	1.5	1.1

Sources: Malaysia (1986a, 1996a, 1999a).

Despite the declining importance of the agricultural sector in the overall economy of Malaysia, the sector continues to play important socio-economic and strategic roles. This multi-functional aspect of the agricultural sector continues to offer important social, economic and political issues and agendas that need to be addressed in agricultural development. Issues pertaining to food security, poverty alleviation and income distribution, balanced development as well as sustainable development in the agricultural sector are critical issues that have important implications for the general welfare of the nation in the long run.

3.2 Salient developments and structural composition of Malaysian agriculture

Malaysia's agriculture has mainly consisted of rubber, which was developed by the British during its colonization days. In the 1950s, there were already some 1.5 million hectares of rubber, the expansion of which was headed by the expanding world antomobile and transport industry (Sekhar 2000). It was the major contributor in terms of GDP in the sector. Paddy was also grown for domestic consumption and there were pockets of backyard fruit gardens and vegetable growing areas. Other economic crops that can be considered significant during the period include coconut and pepper. Agriculture during the period contributed to more than 50% of the country's GDP.

The narrow economic base of the agricultural sector during the period prompted government to embark on diversification strategies. This diversification need became more urgent with the introduction of the cheaper synthetic rubber resulting in dropping prices for natural rubber. Now after more than four decades of independence, the Malaysian agricultural sector has evolved into a more diversified sector, with a highly developed commodity export sector mainly consisting of palm oil, rubber, forestry products and cocoa, an expanding food sector consisting of paddy, livestock and fisheries as well as a developing 'miscellaneous' sector whose value-added is mainly contributed by fruits and vegetables, pepper, coconut and emerging new industries such as floriculture and specialty natural products.

Table 3.3 shows the components of value-added in the agricultural sector for the 1985 – 2000 period. The industrial export commodities continue to dominate agricultural value-added, albeit exhibiting slightly decreasing share. Rubber exports continue to be significant, but are of decreasing importance. The main source of value-added comes from oil palm, which contributed 30.7% to 47.1% of total value added in the agricultural sector. The portion of food commodities in agricultural value-added increased from 18.4% to 22.6%, registering an improvement of about 23% over the 15 year period. Hence, although the dependence on rubber for growth in agriculture during the early days of agricultural development has been drastically reduced over the years, the dependence has now shifted to oil palm. Diversification from rubber to oil palm has been highly successful, but economic diversification into other crops such as the food commodities has shown significant but slow progress.

Table 3.3 Agricultural value-added, Malaysia, 1985 – 2000 (RM million in 1978 prices).

Item	1985		1995		2000	
	Value	%	Value	%	Value	%
Industrial commodities	8,545	72.1	11,629	71.6	11,991	67.2
Rubber	2,279	19.2	1,692	10.4	1,371	7.7
Oil Palm	3,604	30.7	6,842	42.2	8,412	47.1
Sawlogs	2,104	17.8	2,255	13.9	1,444	8.1
Cocoa	558	4.7	840	5.2	794	4.3
Food commodities	2,180	18.4	3,361	20.7	4,035	22.6
Paddy	583	4.9	672	4.1	702	3.9
Livestock	396	3.3	866	5.3	1,112	6.2
Fisheries	1,201	10.1	1,823	11.2	2,221	12.4
Miscellaneous	1,126	9.5	1,241	7.7	1,813	10.2
Total	11,851	100.0	16,231	100.0	17,840	100.0

Source: Malaysia (1999), Malaysia (2000).

The dominance of oil palm is also reflected in agricultural exports. Currently, palm oil products account for more than 30% of agricultural exports. Other significant exports are rubber, food products and also forestry products.

3.2.1 Agricultural land use

Table 3.4 shows agricultural land use over the last three decades from 1970 to 2000. The dominance of rubber in 1970 quickly shifted to oil palm. Today of the total 6.2 million hectares of agricultural land, 3.3 million hectares are under oil palm. This represents over 53% of the total land use. Rubber is still important with about 1.6 million hectares. However, the area under rubber has been steadily declining, losing a total of 590,000 hectares over the 30 year period. Most of the rubber areas were converted to oil palm. Other crops with large areas are paddy, fruits, coconut and cocoa. The agricultural land use pattern indicates that the expanding subsectors are oil palm, paddy, vegetables and fruits, while the subsectors with negative growth are rubber, cocoa and coconut. Area under tobacco and vegetables has somewhat stabilized.

Table 3.4 Agricultural land use, Malaysia, 1970 - 2000 ('000 hectares).

Crops	1970	1985	1990	1995	2000
Oil palm	320.0	1,482.4	2,029.5	2,539.9	3,338.3
Rubber	2,181.8	1,948.7	1,836.7	1,679	1,590
Cocoa	n.a.	303.9	419.1	190.7	111.4
Paddy	533.4	655	680.6	672.8	692
Coconut	348.64	334.1	315.6	248.9	115.7
Pepper	10	5.4	11.5	10.2	10.9
Vegetables	n.a.	31.8	35.2	42.2	32.1
Fruits	n.a.	150.1	204.6	257.7	261.7
Tobacco	n.a.	16.2	10.2	10.5	18.5
Others	n.a.	70.6	85.2	90.4	14.5
Total	n.a.	4,998.2	5,628	5,742.3	6,185.1

Sources: Malaysia (1970), Second Malaysia Plan.
Malaysia (1999), Third National Agricultural Policy (NAP3).

3.3 Some policy dimensions in agricultural development

The strategic multi-faceted role that agriculture plays in national development has prompted many governments to institute various policy instruments to influence social, economic and financial outcomes in the sector. The situation is no different in Malaysia. The country believes that the economic and social health of the sector is a crucial pre-requisite for social, economic and political stability of the nation. This stability has provided the foundation for further growth and development in Malaysia. It is not an overstatement to say that the vigorous economic growth and the accumulation of wealth enjoyed by the nation thus far has been due to the strong economic foundation of the agricultural sector, which provides spin-offs for investments and growth in manufacturing and services.

All the policies and programs in the agricultural sector are formulated based on the above philosophical background. They are designed not only to generate economic growth in the sector per se but are also to address the other interests of the nation. Many programs in the sector are implemented to fulfill the strategic needs of the sector and the nation. This includes issues and objectives to serve:

- food security,
- income enhancement, poverty alleviation and better income distribution between farming and non-farming communities,
- as a "buffer" during bad economic times, and
- rural employment.

3.3.1 Food security

Malaysia is of the opinion that it is not in the best long term interest of the nation to be too dependent on external sources of supply for food. The policy on food as stipulated in the Malaysian Third National Agricultural Policy is to ensure adequate and stable supply of quality, safe, nutritious and reasonably-priced food to meet the needs of the nation. However, the implementation of the food security objective is currently only limited to rice, where there is direct intervention of the government in the market-place (Tengku Ariff and Ariffin Tawang 1999). Since the First Malaysian Plan, Malaysia has emphasized the need to produce its own food, hence the 100% self-sufficiency level (SSL) target for rice production during the early period. At present, the SSL target for rice has been reduced to 65% of national requirement due to the move towards a liberalized and a more competitive agricultural sector. Despite the downward revision for the SSL for rice, the importance of the food security objective is not being compromised. However, the strategy in pursuing the SSL has been more market-based through the provision of incentives and strengthening the economic foundation to increase competitiveness of the food sector. The SSL for Malaysia's main foodstuffs for 1985 – 2000 can be seen in Table 3.5.

Malaysia has learnt from the recent financial crisis. The devaluation of the local currency against the US dollar during the crisis resulted in high import costs and escalating food prices in the domestic market. The food import bill increased by more than 30% to more than RM 12 billion as a result of the crisis. This has threatened the stability and security of the country's food supply.

The El Nino phenomena, if prolonged and left unchecked, can have similar impacts as the financial crisis on the food sector. It can result in depressed domestic food production leading to high imports and high prices for the consumer.

Table 3.5 Self-sufficiency levels (%) in food commodities, 1985 – 2000.

Commodity	1985	1990	1995	2000
Rice	73.5	79.4	76	73
Fruits	101.8	110.4	99	99
Vegetables	80.8	75.2	71	75
Fish	94.9	91.1	95	89
Beef	43.0	23.8	19	21
Mutton	9.4	10.5	6	6
Poultry	108.6	113.9	111	128
Eggs	103.3	109.4	110	113
Pork	103.3	106.3	104	62
Milk	4.0	4.3	4	4

Source: Malaysia (1999), Malaysia (2000).

3.3.2 Social security and poverty alleviation

Agricultural development in Malaysia is also aimed at enhancing incomes of the rural community. Many of the country's poor are in agriculture and residing in the rural areas. During the colonial era, poverty programs were almost non-existence. Development programs mostly emphasized the development of urban areas with the assumption that the 'trickle-down' effect of economic development and the work of Adam Smith's 'invisible-hand' would spread itself to the rural areas. Various reviews and studies indicate that this approach had fallen short of expectations (Engku Aziz 1964; Chamhuri 1987; Mohd Sukri 1992). The high disparity of incomes between the rural population, which mainly consists of Malays, and the urban population, which mainly consists of ethnic Chinese, led to the infamous racial riots in 1969.

Table 3.6 gives an indication of the prevalence of poverty in agriculture during the period. Rural poverty in 1970 was at a high of 68.3%. Incidence of poverty in the paddy subsector was at 88.1%, fishermen (73.2%), rubber smallholders (64.7%) and coconut smallholders (52.8%).

Table 3.6 Number of poor households in agriculture, Peninsular Malaysia, 1970.

Subsector	Total Households ('000)	Total Poor Households ('000)	Incidence of Poverty (%)
Rubber	350.0	226.4	64.7
Oil palm	6.6	2.0	30.3
Coconut	32.0	16.9	52.8
Paddy	140.0	123.4	88.1
Other agriculture	137.5	126.2	91.8
Fishermen	38.4	28.1	73.2
Estate workers	148.4	59.4	40.1
Total	852.9	582.4	68.3

Source: Malaysia (1976). Third Malaysia Plan, 1976-1980, Kuala Lumpur.

It was then that a higher priority was given to rural development and poverty by increasing budgetary allocations, establishing rural and agriculture-related development institutions, providing physical infrastructure and implementing a diversified range of agricultural development programs. Integrated agricultural development projects (IADPs) were established to improve *in-situ* conditions. This is especially so in paddy growing regions where a range of support services including irrigation schemes were developed. Subsidies were also given to paddy farmers to assist them in obtaining higher returns from paddy cultivation.

The early strategy of the government to redress poverty also involved the provision of land and capital to the rural poor through massive development of new land. It was then that government agencies such as FELDA, FELCRA (Federal Land Consolidation and Reclamation Authority) RISDA (Rubber Smallholder Development Authority) and other state government agencies developed land, planted mostly with rubber and later with oil palm, to be distributed to the landless poor. This program has been highly successful and has become an exemplary showcase of Malaysia's effort in improving income of the rural poor (Mohd Arif Simeh and Tengku Ariff 2001).

The above two issues on food and social security have highlighted the important implications of any exogenous effects such as the El Nino on crops such as paddy, rubber and palm oil. The stakes can be high for Malaysia. Adverse effects on yields of these crops will not only mean economic loss to the nation, but it would also mean lower incomes to the nation's poorest. This can have far reaching consequences.

3.4 Institutions in agricultural development

Institutional framework is an important enabler for growth and the implementation of agricultural programs to achieve social objectives. Realizing the importance of institutions on agricultural development, the government in the 1960s and 1970s established many agriculture related institutions to facilitate and implement programs pertaining to new area development, extension services, research and development (R&D), marketing, farmers' institutions, enforcement agencies, irrigation related institutions and others providing support services to agriculture. Some of these institutions are crop-specific while some are function-based such as for R&D and extension services.

This section will describe some of the institutions that are important in agricultural development.

3.4.1 Institutions for primary export commodities

Malaysian Palm Oil Board (MPOB)

The MPOB is a consolidated palm oil based institution from the Palm Oil Registration and Licensing Authority (PORLA) and the Palm Oil Research Institute of Malaysia (PORIM). MPOB's general function is to ensure the orderly development of the palm oil industry and undertake all aspects of R&D in palm oil to enhance the performance of the industry. MPOB issues licenses to those involved in the production, transportation, storage, export and sale of palm oil and its products. Generally, the regulatory activities of PORLA concern quality control of palm oil and its products (Jailani and Malik 1995). All trade contracts must be registered with the MPOB and traders are required to declare the quality of palm oil to be exported and ensure that the exported palm oil meets the quality specifications as declared in the contract.

Malaysian Palm Oil Promotion Council (MPOPC)

Another institution which is palm-oil based is the MPOPC. The MPOPC undertakes public relations and market promotion of palm oil mainly in export markets. It is run as a private company and promotes palm oil by organizing and participating in trade missions and exhibitions and by distribution of information on the nutritional aspects of palm oil. The organization also facilitates joint-venture programs.

Malaysian Rubber Board (MRB)

The MRB is the custodian of the rubber industry in Malaysia. The primary objective of MRB is to assist in the development and modernisation of the Malaysian rubber industry in all aspects from cultivation of the rubber tree, the extraction and processing of its raw rubber, the manufacture of rubber products and the marketing of rubber and rubber products (Malaysian Rubber Board 2001). It conducts R&D and provides consultancy, training and testing services to the industry.

Malaysian Cocoa Board (MCB)

MCB's function is to conduct and promote research on production, processing, storage and consumption, to improve quality, regulate marketing activities, collect and disseminate information and supervise and coordinate cocoa related activities, which covers processing, storage, regulation and marketing. MCB's role is similar to that of MPOB except that it covers a different crop.

3.4.2 Food crop-based institutions

Malaysian Agricultural Research and Development Institute (MARDI)

MARDI was established with the primary objective of developing and promoting new and improved appropriate technologies in agriculture. These technologies will serve to increase productivity and efficiency, thus modernising the agricultural sector as well as maximising farm income (MARDI 2001). The main functions of MARDI are:

- to conduct scientific, technical, economic and sociological research with respect to the production, utilisation and processing of all crops (except rubber and oil palm) and livestock;
- to serve as a centre for the collection and dissemination of information and advice on scientific, technical and economic matters concerning agriculture, including the publication of reports, periodicals and relevant professional journals and papers;
- to serve as a centre for specialist extension services in the agricultural industry;
- to advise on the training of workers for scientific and technical research and extension;
- to provide grants-in-aid for the purpose of pure and applied scientific, technical and economic research concerning the agricultural industry;
- to maintain liaison with other organisations both public and private, indigenous and foreign; and
- to conduct commercial research and production for effective promotion and utilization of its research findings.

Department of Agriculture (DOA)

DOA is mainly involved in extension activities, transferring new knowledge and technologies from research institutions to producers. It also provides consultancy and technical support services and conducts training. It is also involved in the production and distribution of planting materials and seeds. In addition, it also acts as a regulatory and enforcement body in enforcing the Pesticides Act and the Plant Quarantine Act. The Pesticides Act is to ensure that all pesticides imported, manufactured and sold in the country are of high quality and do not have adverse effects on humans, animals, food crops and the environment, while the Plant Quarantine Act seeks to control the entry of foreign noxious pests and diseases and to facilitate the export of plants and plant products in order to fulfill the phytosanitary requirements of importing countries. Additionally, the DOA also enforces the Customs Order (Prohibition of Exports), and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Agreement to prevent plant species of economic importance from being freely brought out of the country and to prevent the extinction of endangered wild plant species.

Department of Irrigation and Drainage (DID)

Following the Independence of Malaya in 1957, greater emphasis was placed on increasing the income and employment opportunities of the rural poor. Emphasis was also given to self-sufficiency in rice. With this objective, DID's main role was to provide adequate irrigation facilities to enable double cropping of padi lands, and drainage facilities for improved production of tree crops especially in small holdings. Today, the DID's duties encompass irrigation, drainage, river engineering, coastal engineering and hydrology. The department can be regarded as the guardian of the nation's water resources.

Intergrated agricultural development projects (IADPs)

IADPs are established in traditional agricultural areas to increase coordination among the various implementing agricultural development agencies. These areas belong to the paddy growing areas where water management and control is critical. IADP's thus allow effective operational integration among the key players under a single executive authority. The implementing agencies put under one roof of the IADP's can include DID, DOA, MARDI, farmer's associations and also the Federal Agricultural Marketing Authority. There are currently about eight IADPs throughout the country.

3.4.3 Smallholder-based institutions

Federal Land Development Authority (FELDA)

In 1957 a policy for land development was promulgated as a basic strategy to uplift the economic status of the rural sector. The main mechanism was through FELDA, which was entrusted with the task of developing new land that was to be made accessable to the landless poor for productive use. FELDA's model of land development is based on the provision of a highly centralized administration and management. Settlers were brought into the land schemes and were only given subsistence payments until the first crop harvest. Credit facilities and a wide range of support services as well as community services were provided aimed at aiding rapid adaptation and change of the settlers. Today, FELDA has developed over 800,000 hectares of land with more than 100,000 settler families. Most of the land schemes are now covered with oil palm with a small portion under rubber. The FELDA organized smallholder scheme is one of the international showcases of sucessful programs in combating rural poverty.

Rubber Smallholder Development Authority (RISDA)

RISDA's general aim is to improve the socio-economic welfare of rubber smallholders in the country. It is mainly involved in providing re-planting funds to rubber smallholders for up-grading to new rubber clones or to divert into other crops which are more profitable such as oil palm. It is also involved in extension and transfer of technology activities, dissemination of information and the production of quality planting materials.

3.4.4 Environment related institutions

Malaysian Meteorological Service Department (MMSD)

The main functions of the MMSD include the monitoring of weather conditions and seismic activity in the country, issuance of timely meteorological information and forecasts and the provision of advance warnings on the occurrence of adverse weather phenomena and dangerous sea conditions in the Malaysian region. In addition the MMSD also provides climatological and agrometeorological information in support of various climate-sensitive activities, and seismological information to civil engineering and construction industries. The department also monitors air quality and provides information and technical advice on meteorological aspects of air pollution. From tine to time MMSD conducts cloud seeding operations during dry spells to increase water resources for agriculture and other purposes.

Department of Environment Malaysia (DOE)

The DOE is the guardian of Malaysia's environment. Its main function is to administer and enforce the Environmental Quality Act. This is to ensure that the uniqueness, diversity and quality of the environment are preserved towards maintaining health, prosperity, security and well-being for the present and the future (DOE 2001).

Thus, the DOE carries out pollution control and prevention as well as providing environmental inputs to resource and regional development planning. It is also involved in environmental impact assessment, environmental education, training and dissemination of information, environmental research and development.

4. Biological Interaction between Climate Variability and Agricultural Production

Crop growth and production is the end result of interactions between a biological system, i.e. the plant population, and the physical environment in which the plants grow. Two major aspects of this environment have to be considered in agriculture: climate and soils. The basic climatic requirements for crop growth are water (rainfall), temperature, solar radiation, and atmospheric gases particularly carbon dioxide and oxygen. Other climatic factors such as atmospheric humidity, evaporation and wind speed also play an important role with respect to crop growth and production. This chapter examines the biological relationship between crop growth and production and the variability in these climatic factors. The establishment of such relationships could provide some indications of the possible impact of climate abnormality on agricultural performance.

4.1 Natural environmental constraints

Relationships between climate and crops are not simple. One complication is the change in requirements of most crops during their development processes. Perennial crops, for instance, require lots of water in the early stage of growth, but much less when they are well established and have a good root system. Rice is very sensitive to temperature and sunshine in its reproductive stage, but in other parts of its growth cycle these two factors are less important.

A second difficulty is that some climatic elements may have combined effects. For instance, sunshine is a favourable factor in crop growth if water and nutrients are not limiting, because its increases photosynthesis. On the contrary, it may have an adverse effect on crops when combined with drought conditions because water needs are increased.

In the course of plant development, plants adjust to the seasonal periodicity of insolation, day length, temperature and precipitation (its onset and amount). The transitions from one phase to another are the critical steps for temporal adjustment of the life cycle to suitable and unsuitable periods for growth. While the activity of plants in the temperate and cold-climate zones is synchronized with the seasons by seasonal photo- and thermoperiodicity, the growing season in the tropics is limited by increasing water deficiency once the dry period begins. In other words, the phenophases are linked to this hydroperiodic alternation (Larcher 1995).

Therefore, as climatic conditions change with the seasons, the timing of field operations is important, especially for annual crops. It is also possible to improve the microclimate of some crops, for example, by irrigation, mulching, shading and protection from flooding. On the other hand, macroclimate should not be changed, as it is part of the natural environment; thus, the most appropriate methods and production systems in agriculture should be adapted to match it.

4.1.1 Climatic variability and extreme events

Changes in variability are important because they may have a significant effect on agriculture and water resources (Mearns et al. 1996). A small change in variability has a stronger effect on the frequency of extremes than a small change in the mean (Wigley 1985).

Generally, there is no evidence globally that extreme events or climate variability has increased through the 20th century. On a regional scale, there is clear evidence of changes in some extreme events and climate variability. Some of these changes have been toward greater variability, some toward lower variability (Chan and Yap 2000).

4.1.2 Drought

Drought is a complex phenomenon that can be defined from several perspectives (Wilhite and Glantz 1987). It is commonly perceived to be an abnormally long period without precipitation. The central theme in the definition of a drought is the concept of a water deficit. Drought is often the result of many complex factors such that drought often has no well-defined start or end. The impacts of drought vary by affected sector, thus often making definitions of drought specific to particular affected groups.

The most commonly used drought definitions are based on meteorological, agricultural, hydrological and socio-economic effects. Meteorological drought is often defined by a period of substantially diminished precipitation duration and/or intensity. The commonly used definition of meteorological drought is an interval of time, generally on the order of months or years, during which the actual moisture supply at a given place consistently falls below the climatically appropriate moisture supply. Agricultural drought occurs when there is inadequate soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought usually occurs after or during meteorological drought. Hydrological drought on the other hand, refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow, and as lake, reservoir and groundwater levels. Socio-economic drought occurs when physical water shortages start to affect the health, well-being, and quality of life of the people, or when the drought starts to affect the supply and demand of an economic product.

4.2 Water

4.2.1 Water relations and plant growth

Water is the major limiting factor to plant distribution and productivity (Kozlowski 1968; Boyer 1976). External water balance, which controls plant growth and survival, is determined by the relative rates of water loss and water uptake (Slatyer 1967). It is essential to understand how water deficit relates to conditions in the soil and atmosphere and how it influences growth. Soil water supply travels from source (soil) to sink (atmosphere) and uses the plant as transferring media and this pathway of water flow has been termed the soil-plant-atmosphere continuum (SPAC). The SPAC can be considered as series of gradients and resistances for each segment (soil to root, root to leaf, leaf to atmosphere). Water potential (ψ_w) is an expression of the free energy status of water. It is a measure of the driving force, which causes water to move into any system (plant tissue, soil and atmosphere). Water potential is the determinant of diffusional water movement and it is probably the most meaningful parameter that can be measured in the SPAC. Osmotic (solute), matrix, pressure (turgor) and gravitational potentials are components of water potential, their relationship is usually written as:

$$\psi \text{ water} = \psi \text{ osmotic} + \psi \text{ pressure} + \psi \text{ matrix} + \psi \text{ gravitational.}$$

An understanding of water flow through this continuum and of the factors that influence it can provide considerable insight into how plants fit in their environment.

Growth depends upon cell division and elongation and ultimately on carbon compounds from the photosynthetic tissues; both processes are intimately tied to the plant's water balance (Hsiao 1973). Drought or water deficits can inhibit photosynthesis by reducing leaf area, closing stomata, and by dehydration of protoplasm. Plants adapted to growth in arid regions can maintain measurable photosynthetic rates at lower plant water potentials than plants naturally found in humid areas. Stomatal sensitivity to changes in leaf water potential (ψ_{leaf}) differs widely among plants, especially with regard to the water potentials at which reduction in photosynthesis begins, the steepness of its decline, and the potential at which photosynthesis become negligible (Boyer 1976). Since stomata act as regulators of water loss, water deficits sufficient to close stomata must also depress photosynthesis. With increasing water stress photosynthesis declines initially as a result of stomatal closure, but prolonged and severe water stress can lead to depression of chloroplast and enzyme activity (Boyer and Potter 1973). Plants with high water use efficiencies at high levels of water stress and/or delayed stomatal opening following rewatering after drought might compete successfully on drier sites.

4.2.1.1 Drought avoidance and resistance

The ability of a crop variety or species to grow satisfactorily in areas subjected to periodic water deficits has been termed drought resistance (May et al. 1962). When considering the effects of water deficit on plants, drought may be defined as an environmental condition which produces internal water deficits that interfere with physiological processes, causing reduction in growth or death by dehydration (Kramer and Kozlowski 1979). Drought resistance can be divided into three components: drought avoidance, drought tolerance and drought recovery (Larcher 1995). Drought avoidance is related to the plant's ability to avoid dehydration resulting from modifications of anatomical, morphological, and physiological characters (Seidel 1972), which reduce the impact of the stress. Some avoidance mechanisms include timing of stomatal closure, stomatal morphology and leaf abscission.

Drought tolerance is related to the plant's ability to survive dehydration and is dependent on the inherent properties of the protoplasm that enables tissues to endure protoplasmic loss of water or low water potential without lethal injury (Seidel 1972). Drought tolerance characters include osmotic adjustment, decreased cell wall elasticity or increased percentage of bound water. Drought recovery on the other hand, is the plant's ability to regain normal physiological function after the stress.

4.2.2 Water requirements and crop growth

When relations between the climate of Malaysia and agriculture are discussed, most attention should be devoted to the influence of rainfall. The availability of water is important to determine the success or failure of crops.

In the tropics, rainfall is the most variable element of climate. Large annual differences in agricultural production are almost entirely caused by variation of rainfall. An adequate supply of water is essential for all forms of agriculture. Water needs vary widely with the various types of crops and their growth stages. Thus, rainfall is often the limiting factor in agriculture, both when there is insufficiency and when there is a surplus.

The response of various crops to water stress or drought differs. Perennial crops are not very affected compared to annual and shallow-rooted crops such as vegetables, tobacco, maize and groundnut. Moisture stored in the soil acts as an efficient reservoir between rainfall to satisfy crop water needs. Short-term irregularities of rainfall are normally smoothed out by this reservoir and moisture stress in perennial crops is prevented. The distribution and total amount of rainfall are important factors which could exert a negative effect on the growth and productivity of many crops. On the other hand, drought or insufficient rainfall also has positive effects. Perennial crops e.g. mango, durian, mangosteen, will not flower properly unless they have been through a period of moisture stress (Hacket and Carolane 1982; Chan and Tay 1982). For some annual crops e.g. rice, maize, sugarcane, a dry period is a definite advantage in terms of produce quality.

Rainfall in tropical areas is generally high. Total annual rainfall is between 1000-2000 mm without a pronounced dry season, but a drier period with a few months having less than 100 mm occurs (Jackson 1989). Unseasonal events of excessive rainfall can cause unexpected crop failure in many parts of the world. When the rainfall is in excess of soil moisture storage capacity and evaporative demand requirements, surface soil will be saturated. When deep percolation is exceeded by rainfall intensity, surface flooding will occur. Apart from floods, soil saturated with water also has an adverse effect on crop growth and yield. The nutrients are washed out from the soil and nutrient uptake is also reduced because of poor aeration in the root zone. These effects are most serious for short-term and shallow-rooted crops because they lack time and space to overcome these disadvantages while tree crops normally experience a temporary standstill in growth (Foster et al. 1981).

4.3 Temperature

4.3.1 Temperature requirements and crop growth

Generally, temperature conditions have a profound effect on plant growth. The effect of temperature on crops mainly governs the timing of physiological processes, the rate of expansion and the survival of individuals or reproductive structures. Temperature has the greatest effect when other climatic factors such as solar radiation and water are limiting. For example, when the soil moisture is limiting, temperatures affect yield mainly by determining the times to flowering and later reproductive processes.

Photosynthesis is one of the most heat sensitive aspects of plant growth. Plants differ greatly in their potential for photosynthesis acclimation to temperature regimes of their native habitats (Bjorkman et al. 1980). Photosynthetic differences at low temperature are strongly correlated with the capacity of specific rate limiting components such as enzymes RuP2 carboxylase and FruP2 phosphatase. However, at high temperature the limitation to photosynthesis is imposed primarily by the thermal stability of chloroplasts. Increased thermal stability evidently involves changes in the properties of the thyllakoid membranes as well as perhaps the soluble enzymes outside these membranes (Bjorkman et al. 1980).

Perennial and annual crops react differently to temperature. For each type of crop, extreme temperature limits exist as well as a range of optimum temperatures. Lowland crops generally need temperature in the range of about 25-35^{o}C to perform best (Hackett and Carolane 1982). They can survive at lower temperature, but their growth is slower, yield is lower and they are more susceptible to diseases, especially when the temperature is frequently below the optimum range.

Generally, the influence of this factor in crop selection, production and agricultural planning is minor (Nieuwolt 1982) but crop responses to different temperatures can be distinguished. Low temperature is normally not a limiting factor to crop growth and production in the tropics except at high altitude. However, in highland areas, certain crops, especially temperate and subtropical fruit trees require a period of low temperature or a chilling period for initiation and development of flower buds and fruits.

Many tropical crops can tolerate higher temperatures. However, adverse effects of high temperature can occur, commonly associated with water stress. In relation to temperature response, higher temperatures generally shorten the duration of the successive and finite stages of growth (e.g. leaf emergence, flowering, grain filling, ripening) and consequently shorten the duration of the season. Therefore, warmer temperature will decrease the yield of determinate crops such as cereals (Monteith 1981; Wheeler et al. 1996). In contrast, indeterminate crops such as root crops continue to produce leaves and to grow for as long as the temperature remains suitable and so yields of these crops tend to increase as temperature rises.

4.4 Radiation

Solar radiation is an important environmental factor in agricultural production. The visible portion of solar radiation known as the photosynthetic active radiation (PAR: 400-700 μm) is the most important component affecting photosynthesis and overall plant growth. Apart from providing irradiance required for photosynthesis, solar radiation is also needed for other physiological functions such as thermal conditions required for the normal physiological functions of the plants. Transpiration and photosynthesis are two physiological processes that increase almost in proportion to the intensity of solar radiation.

Diffuse radiation received during cloudy days is generally sufficient for photosynthesis. Direct sunshine will increase the rate of photosynthesis up to the point of saturation light intensity. The saturation light intensity varies strongly with various crop species and growing stages (Squire 1990). When more sunshine is received than needed for the saturation light intensity, net photosynthesis decreases.

Solar radiation is closely related to sunshine duration. Its seasonal and spatial variations are thus very much the same as in the case of sunshine. There are, however, seasonal and spatial variations in the amount of sunshine received. Sunshine requirement varies strongly among the crops. For most tropical crops the optimum amount of sunshine is about 3-4 hours (Hackett and Carolane 1982). However, some crops need a higher amount of sunshine. Rice, for example, will yield higher when it receives up to 6 hours of sunshine per day. Variation in sunshine intensity during vegetative stages does not have any significant effect on yield and yield components. Relatively high solar radiation during the reproductive stage has remarkable effects on increasing spikelet number and grain yield (Yoshida and Parao 1976). On the other hand, low solar radiation generally will reduce rice yield in many tropical areas (Seshu and Cady 1984).

Meanwhile, most of the perennial crops show a positive reaction to sunshine. Fruit trees such as starfruit, mango, citrus and papaya need much sunshine for flavour development (Wong and Mohamad Zabawi 1990). Studies on oil palm (Kraalingen et al. 1989) show that a difference of 1 hour of sunshine per day influences the yield by 15-20 kg bunch dry matter per palm per year. The influence of sunshine duration on yield is quite large and it possibly benefits the areas that receive more radiation.

4.5 Anthropogenic stress

4.5.1 Components, status and trend

The atmosphere has an effect like a greenhouse on the earth’s temperature. The energy from the sun reaching the earth is balanced by the energy the earth emits to space. Greenhouse gases trap some of the energy the earth releases to space. The greenhouse gases in the atmosphere act as a thermostat controlling the earth’s climate. The term "greenhouse" is used to describe this phenomenon since these gases act like the glass of a greenhouse to trap heat and maintain higher interior temperatures than would normally occur. The atmospheric gases most responsible for this effect are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). This "greenhouse effect" occurs naturally in our atmosphere and is responsible for the earth's moderate surface temperature. Water vapour and carbon dioxide are the largest contributors to the natural greenhouse effect due to their overall abundance in the atmosphere. Methane, although at very low atmospheric concentrations, is a much more efficient absorber of infrared radiation than either H_2O or CO_2.

Apart from these gases, several classes of halocarbons that contain fluorine are also greenhouse gases. Fluorine-containing halocarbons include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). These greenhouse gases are generated exclusively by anthropogenic (human-related) activities. Currently, atmospheric concentrations of these gases are small relative to other greenhouse gases. However, they may remain in the atmosphere almost indefinitely, and concentrations of these gases will increase as long as emissions continue. These compounds, have the potential to greatly impact global warming and subsequently climatic variability due to their potency and extremely long atmospheric lifetimes (Table 4.1).

Table 4.1 Changes in greenhouse gas concentrations due to human activities.

	CO_2	CH_4	N_2O	CFC-11	HCFC-22	CF_4
Pre-industrial concentration	~280ppmv	~700ppbv	~275ppbv	Zero	Zero	Zero
Concentration in 1994	358ppmv	1720ppbv	312ppbv	268pptv	110pptv	72pptv
Rate of concentration change	1.5 ppmv/yr 0.4%/yr.	10ppbv/yr 0.6%/yr.	0.8ppbv/yr 0.25%/yr	0pptv/yr 0%/yr.	5pptv/yr 5%/yr.	1.2pptv/yr 2%/yr.
Atmospheric lifetime (years)	50-200	12	120	50	12	50,000

Source: IPCC (1995).

Since the beginning of the Industrial Revolution about 200 years ago, atmospheric concentrations of greenhouse gases including CO_2, CH_4 and N_2O have risen substantially. These increases are a result of a variety of anthropogenic (human) activities such as the production and use of fossil fuels, as well as other industrial and agricultural activities. It is now recognised that anthropogenic activities are constantly changing the concentrations and distribution of the greenhouse gases as well as aerosols in the atmosphere.

4.5.2 Effects of anthropogenic stress on climatic variability

The concentrations of atmospheric greenhouse gases have been increasing since the pre-industrial days. The expected effect of these increasing concentrations is the warming of the lower troposphere and the surface of the earth. Based on the results of some General Circulation Models (GCMs), the mean temperature in Malaysia is projected to rise in the range of 0.6^{o}C to 4.5^{o}C when the concentrations of atmospheric greenhouse gases double. Rainfall changes may range from minus 10% to plus 30% (Chan and Yap 2000).

Based on the Climate Change Atlas prepared by Henderson-Sellers and Hansen (1995), the changes in magnitude for rainfall and temperature over the Malaysian region due to doubling of CO_2 are tabulated in Table 4.2. This atlas was constructed using outputs from various climate change models incorporating a variety of enhanced greenhouse gas scenarios. It is clear from the Table 4.2. that the range of values particularly for precipitation is very large. Such large range values may not be very meaningful for impact assessment (Chan and Yap 2000).

Table 4.2 Changes in Malaysian climate after doubling of CO_2.

Period	Jan	April	July	Oct.
Changes in Temperature	0 to 4^{o}C	0 to 4^{o}C	0 to 4^{o}C	0 to 4^{o}C
Changes in Rainfall	-5 to +5 mm/d	-5 to +10 mm/d	-5 to +5 mm/d	-5 to +10 mm/d

Source: Extracted from Climate Change Atlas by Henderson-Sellers and Hansen (1995).

4.5.3 Air pollution and haze

The composition of the atmosphere has changed markedly since pre-industrial times. Human activities through fossil fuel burning, land use changes, agricultural activity, the production and use of halocarbons and others are the dominant cause of these changes. The atmospheric concentrations of nitrogen dioxide, carbon monoxide, ozone and total suspended particulate matter are becoming prominent features of the Malaysian meteorological conditions in the last two decades, as mentioned previously.

Due to the sudden and short-term occurrence of haze episodes, proper studies on the effects of haze on agricultural crops are very scarce. The most obvious effect is the low level of photosynthetically active radiance (PAR) for crop photosynthesis. Observations in Serdang (Klang Valley) indicated PAR as low as 50 µmole $m^{-2}s^{-1}$. This low value is equivalent to the light compensation point for most of the C_3 species. Generally, there was a reduction of about 70% under shaded and 40% under open environments (Mohd Nasir et al. 1999). For many annual crops, low PAR values drastically reduced the rate of photosynthesis and in some cases the rate of respiration may exceed photosynthetic rates and eventually affecting dry matter production.

Under longer duration, leaves may be covered with settled particulate matter that in turn prevents stomata from functioning normally. Under this condition, most physiological processes related to leaf gas exchange such as photosynthesis, transpiration and stomatal conductance may be affected.

4.6 Impact of weather change and variability on major Malaysian economic crops

4.6.1 Rice

4.6.1.1 Climatic requirements

The rice plant has its origin in the tropics and is presently grown under more diverse environmental conditions than any other major crop in the world. It can be grown in both temperate and hot tropical climates, from sea level to high altitude. The climatic features suitable for irrigated and rainfed rice cultivation are shown in Table 4.3 (Sys et al. 1993). Long periods of sunshine are essential for high yields. The yields are correlated with the solar energy received during the 45 days that precede the harvest. Growth is optimal at air temperatures between 24 and 36°C. The difference between day and night temperatures should be minimal during flowering and yield production. The irrigation water temperature is required to be >18°C.

Table 4.3 Climatic requirements for rice cultivation.

Climatic Characteristic	Degree of Limitation				
	None	Slight	Moderate	Severe	Very Severe
Mean daily air temperature (^{o}C)	28-25	24-22 29-30	21-20 31-32	19-18 33-34	<18 >34
Mean daily maximum air temp. (o C)	34-29	28-27 >34	26-24	23-22	<22
Mean daily minimum air temp. (^{o}C)	>20	20-19	18-17	16-17	<16
Mean annual rainfall (mm)	>2000	2000-1750	1749-1500	1499-1250	<1250
Expected total rain interference (days/yr)	0-30	31-60	61-90	>90	
Sunshine length (hours/yr)	>2100	2100-1800	1799-1400	1399-1000	<1000
Maximum wind speed (m/see)	0-7	8-14	15-21	22-30	>30
Mean annual R. H[1]	<80	80-100			
Length of dry season (months/yr)	0-1	2-3	4	5-6	>6

Source: Sys et al. (1993).
Note: [1] R.H.: Relative Humadity.

4.6.1.2 Effects of climatic change and variability

The impact of climatic variability as a result of temperature and precipitation extremes, as well as climatic change, on rice production has been subjected to many scientific investigations, due to its importance as a staple food crop and energy provider for over half of the world's population.

Water deficit

Under conditions where temperature and water are not limited, solar radiation has pronounced effects on rice yield. However, under rainfed conditions, the onset, distribution and the amount of rainfall will determine yield variability.

With the occurrence of water deficits, many of the physiological processes associated with growth are affected and under severe deficits, death of plants may result. The effect of water stress may vary with the variety, degree and duration of water stress and the growth stage of the rice crop. Water deficit at any stage would reduce the yield. However, the duration of this stress is more closely correlated to the yield reduction than the stage at which the stress occurs (IRRI 1970).

Water requirement is low at the seedling stage. Unless there is severe water stress the effect during this stage could be recovered. Water stress during the vegetative stage reduces plant height, tiller number and leaf area. However, the effect during this stage varies with the severity of stress and age of the crop. Long duration varieties suffer less yield damage than short duration varieties, since the long vegetative period could help the plant to recover when water stress is relieved.

Leaf expansion during the vegetative stage is very sensitive to water stress. Cell enlargement requires turgor to extend the cell wall and a gradient in water potential to bring water into the enlarging cell. Thus water stress decreases leaf area, which reduces the intercepted solar radiation. Rice leaves in general have a very high transpiration rate. Thus under high radiation levels, rice plants may suffer due to mid day wilting. The rice plant can transpire its potential rate even when soil moisture is around field capacity. Under local conditions, transpiration was found to be the highest at the flowering stage followed by the maximum tillering stage (Matsushima 1962). Therefore maintaining a saturated water regime through the crop duration is best for saving water and increasing grain yield. In general the rice plant uses less than 5% of the water absorbed through roots from the soil. The rest is lost through transpiration, which helps to maintain the leaf energy balance of the crop. Decreased leaf water potential closes stomata and decreases transpiration, which in turn increases leaf temperature.

Rice is most susceptible to water stress during the reproductive stage. Water stress at or before panicle initiation reduces panicle number most, but all stresses regardless of crop stage or duration significantly reduce panicle number. Water stress after panicle initiation reduces the potential spikelet number. Water stress at heading reduces the rate of exertion of the panicle. Anthesis and ripening stages are the most sensitive stage for water stress. Water stress during anthesis increases unfilled spikelets. Spikelet sterility decreases with decreased leaf water potential during the meiotic stage of pollen development. Mild stress affects sink more than source, whereas severe stress affects both. Stress during grain filling decreases translocation of assimilates to the grain which decreases grain weight and increases empty grains. Increased canopy temperature above 28^{o}C due to water stress linearly increases relative spikelet sterility. Water stress during the grain filling stage should also be avoided in order to maintain good grain milling quality (Turner and McCauley 1983).

Water requirement

Water requirement for a successful rice crop varies with the soil, environmental conditions, crop establishment methods and duration of the rice crop. Main determinants of water requirement are evapotranspiration, seepage and percolation rates. With good management practices, water losses due to seepage and percolation can be minimized. Evapotranspiration from a rice crop canopy is a function of the size of the crop (leaf area index), water availability and the environmental conditions. Evapotranspiration increases as leaf area increases and it is also influenced by temperature. Temperature requirements also vary with growth stage, with optimum temperature ranges of 25-30, 25-31, 30-33 and 20-29^{o}C for seedling, tillering, anthesis and ripening stages, respectively (Anon 1993). The evapotranspiration crop coefficients in rice are 1.1 from seedling through tillering stage, and 0.95 at anthesis through ripening stages (Doorenbos and Kassam 1979). Generally, evapotranspiration is low at early stages of crop growth and achieves a maximum towards heading. Hence the frequency of irrigation should increase accordingly towards flowering to meet the increasing demand for water.

Water has become a scarce and precious commodity especially in the northern region of Malaysia where the main rice granary is located. Studies on water demand projection and potential water resources indicate that the water deficit situation will continue to occur even with all available water resources fully developed (Foong and Chiang 1993). With increasing occurrence of climatic variability, such as drought and reduction in precipitation, measures should be taken against the aggravating drought crisis.

Drought tolerance

The ability of a plant to grow satisfactorily when exposed to periods of water stress is called drought resistance. Mechanisms of drought resistance in rice could be tolerance, avoidance, escape or recovery. The “true” drought avoiding plants could possess mechanisms to maintain favourable water status, either by conserving water or by their ability to supply water to above ground organs even during drought stress. Root depth is a plant trait most strongly related to drought avoidance in upland rice culture. The rice plant can escape or evade drought through the adjustment of the life cycle, which is also an important trait for drought resistance. Leaf rolling or reduced leaf area, stomatal closure and delayed flowering under water stress conditions compared to well watered conditions could be escape mechanisms. Tolerance implies the ability of the plant tissues to withstand water stress. The degree of tolerance in rice varies among varieties and among growth stages within a variety. Recovery of a rice plant after surviving drought stress varies with the variety, the severity of stress and the growth stage.

Temperature

The adverse effects of high and low temperature on rice production differ with cultivar and plant part. Nishiyama (1976) has identified four critical temperatures which affect different physiological properties of rice plants, namely, 0-3ºC, 15-18ºC, 30-33ºC and 45-48ºC. The favourable temperature range for physiological processes is within 17 to 32ºC, however, the temperature below 17ºC would only apply to cool-tolerant rice in high altitude areas. Temperature affects rice growth in two ways, first, a critically low or high temperature defines the environment under which the life cycle can be completed; secondly, within the critically low and high temperature range, temperature influences the rate of development of leaves and panicles and the rate of ripening, thereby fixing the duration of growth of a variety under a given environment and eventually determining the suitability of the variety to the environment (Yoshida 1981).

Generally, the effect of increasing temperature above the tolerance limit on rice potential production is negative. Temperature above the optimum level may reduce photosynthesis, increase respiration and shorten the vegetative and grain-filling periods. Assuming that radiation levels are not significantly affected, 1ºC reduction in the temperature corresponds with an increase in potential yield of 400 kg/ha.

Grain yields are affected much more strongly by temperature than by CO_2. It has been shown that grain yield is negatively correlated with air temperatures above 35ºC during the reproductive phase of growth (Yoshida and Parao 1976). At high temperatures, spikelet sterility is induced almost exclusively on the day of anthesis (Satake and Yoshida 1978). Temperatures greater than 35ºC for more than 1 hour induce a high percentage of spikelet sterility (Yoshida 1981).

Presently, the average temperature in rice-growing areas in Malaysia is about 26ºC. It was shown that for indica rice the optimum temperature range for maximum grain weight is 19 to 25ºC, (Yoshida and Hara 1977). Detailed studies of growth responses to varying temperature for our local varieties are not available. An examination of the current climatic scenario, particularly with respect to growth temperature, reveals that our rice plants are already in the optimum temperature region. Depending on the magnitude of increase, overall growth and productivity may be affected by the increase in temperature under future climatic change or variability. Temperatures above 25ºC may cause a decline in individual grain mass of 4.4% per 1ºC rise (Tashiro and Wardlaw 1989). Under climatic change, the number of panicles may increase due to the positive effect of elevated CO_2, but filled grain per panicle may decrease sharply with increasing temperature. Grain yield may decline as much as 9.6 to 10% for each 1ºC rise in temperature (Baker and Allen 1993).

Carbon dioxide

The average potential yield of current rice varieties is about 10 tons ha^{-1} in the tropics and over 13 tons ha^{-1} in temperate regions (Yoshida 1981), exact values depending on the weather during the season and the specific varieties used. In Malaysia the potential yield for a modern high yielding variety (e.g. MR 84) was simulated to be around 7.2 tons ha^{-1} (Singh et al. 1996). The actual farm yields on the other hand vary between 3 and 5 tons ha^{-1}.

To date, there is no available experimental data on the response of local rice varieties to climatic change or variability. However, based on experimental data obtained elsewhere, the rice crop, in general, responds positively to an increase in atmospheric CO_2 concentration. The increase in biomass was reported in the range of 30 to 40% (Ziska et al. 1997). The overall developmental rates of the rice crop were accelerated in response to an increase in CO_2 concentration from below ambient (160 ppm) to 900 ppm. The growth duration was also shortened by approximately 12 days (Baker and Allen 1993). The growth enhancement and biomass increase under CO_2 enrichment is often associated with rapid growth during the vegetative phase which results in an increase of tiller number (Imai and Murata 1976; Baker and Allen 1993; Ziska et al. 1997). Greater grain yield under CO_2 enrichment was due to an increase in panicle number per plant (Imai and Murata 1976; Baker and Allen 1993; Ziska et al. 1997); however, the number of filled grains per panicle and individual seed mass were unaffected (Ziska et al. 1997). The yield response to CO_2 varies with cultivar, location and management practices. Under field conditions, the highest response of 40% in the wet season was reported in IRRI (Ziska et al. 1997). A non-significant increase in grain yield was also reported by others (Baker et al. 1992).

Under elevated CO_2, with an adequate water supply, nitrogen supply (particularly at the present recommended rate) may become a constraining factor for high yield in most modern varieties.

In general, the average yield increase in response to CO_2 enhancement was only 15%, which is considered low compared to many other agricultural crops (Rogers and Dahlman 1993). Assuming other environmental variables are more or less constant, the increasing trend of CO_2 should have a beneficial effect on growth and yield of rice. It was postulated that the average response amounts to an increase of potential yield (the maximum yield obtainable as limited only by radiation and temperature; nutrient and water are available in surplus) of about 10 kg/ha/ppm CO_2 or about 15 kg/ha/yr. This value is almost independent of location and cropping season (Penning de Vries 1993).

Besides CO_2 and temperature, solar radiation may also change as a result of climatic change. The effect of solar radiation may not be as important as that of temperature and CO_2, but the changes in radiation levels are the most uncertain (Penning de Vries 1993). Solar energy provides two essential needs of plants namely light required for photosynthesis and other physiological functions such as thermal conditions required for the normal physiological functions of the plants. Transpiration and photosynthesis are two physiological processes that increase almost in proportion to the intensity of solar radiation. It has been postulated that in rice a 1% change in radiation level corresponds to about 0.5% change in potential yield or 40 kg/ha (Penning de Vries 1993).

The study conducted by Baker and Allen (1993) has shown no interactive effects between CO_2 and temperature in relation to biomass, yield components and grain yield. A similar observation was obtained in an experiment under field conditions (Ziska et al. 1997).

The latter has shown that flowering and grain-filling periods were markedly affected by an increase in temperature above the present ambient level. The degree of high temperature-induced sterility (as determined from percent filled spikelets) was not reduced with increased CO_2, but appeared to increase with increasing growth temperature and CO_2 level. The grain yield may decline further if the amount of solar radiation is reduced (Baker et al. 1992). The grain quality, particularly protein level, may also be reduced as the result of increase in temperature and CO_2 (Ziska et al. 1997).

A study on simulated impact of climate change on rice production in Peninsular Malaysia was recently undertaken (Singh et al. 1996). The study used a local cultivar of MR 84. Three rice granary areas were chosen (Kemubu, Telok Chengai and Tg. Karang). Using the Oryza 1 rice model, these workers predicted the performance of MR 84 across the three granary areas with respect to various combinations of CO_2 and temperature. Their results indicated a decline in grain yield between 4.6 to 6.1% per 1ºC under the present CO_2 level. Greater yield reduction is envisaged with increasing temperature at higher CO_2 levels. However, a doubling of CO_2 concentration (from the present 340 to 680 ppm), may offset the detrimental effect of 4ºC (as predicted by all GCM models) rise in temperature.

Predicted changes in yield potential, as affected by climate variability (temperature and precipitation extremes) are given in Table 4.4. Predictions are based on the following assumptions:

- Indica rice has an optimum temperature of 19 to 25ºC, for maximum grain weight (Yoshida and Hara 1977).
- In Malaysia the current potential yield is about 7.2 tons/ha (Singh et al. 1996) for modern high yielding varieties (e.g. MR 84)
- For every 1ºC reduction in temperature above the optimum temperature, the yield potential increases by 400 kg/ha (Pening de Vries 1993).
- There will be an increase in yield potential of 10 kg/ha for every 1 ppm increase in CO_2 (Penning de Vries 1993)
- Interactions of climatic components are not considered due to the lack of experimental data. Yields are calculated based on beneficial effects of CO_2 above the present level, the negative effects of temperature (above growth temperature of 27ºC) and reduction in solar radiation.

Table 4.4 Projected rice yield (kg/ha) with climate variability.

CO_2 (ppm)	400	400	400
Temp (ºC)	0.3	0.85	1.4
Rainfall			
+14%	6,146 (-14.7%)	5,806 (-15.4%)	5,586 (-8.4%)
+7%	6,646 (-7.7%)	6,306 (-8.1%)	6,086 (8.4%)
+0.40%	7,202 (0%)	6,862 (0%)	6,642 (0%)
0 (current)	**7,202**	**6,862**	**6,642**
-0.40%	7,202 (0%)	6,862 (0%)	6,642 (0%)
-7%	6,698 (-7%)	6,382 (-7%)	6,177 (-7.0%)
-14%	6,194 (-14%)	5,901 (-14%)	5,712 (14%)

Source: Krishnan et al. (2000).

The above table indicate the projected reduction in rice potential yield (percentage changes) under scenario of temperature ad precipitation extremes. The increase or decrease in the total rainfall from the present rainfall requirement may reduce the current yield (7,202 kg/ha) between 7 to 14%. The magnitude of reduction in potential yield is similar under all conditions of temperature increase. There is also a projected reduction in yield potential of 4.7% and 7.8% due to temperature increase of 0.85ºC and 1.4ºC respectively.

4.6.2 Oil palm

4.6.2.1 Climatic requirements

The oil palm is best suited to a humid tropical climate in which rain occurs mostly at night and days are bright and sunny (Williams and Chew 1979; Hartley 1977). There is a direct relationship between the amount of sunshine received and yield when there is sufficient moisture for growth. Minimum monthly rainfall for optimum yield is around 150 mm and the best climates are those in which there are no dry seasons and sunshine is evenly distributed and exceeds 2000 hours per year. A mean maximum temperature of about 29-33°C and a mean minimum temperature of about 22-24°C favour the highest bunch production. The climatic requirements for oil palm production (Sys et al. 1993) are summarised in Table 4.5.

4.6.2.2 Effects of climatic change and variability

When mean annual temperatures vary from 28°C to 31°C in Peninsular Malaysia as a result of climatic change, these higher temperatures are favourable to high fruit production (Table 4.5).

Table 4.5 Climate requirements for oil palm cultivation.

Climate Characteristic	Limitations				
	None	Slight	Moderate	Severe	Very Severe
Annual rainfall (mm)	>2,000	2,000-1,700	1,700-1,450	1,450-1,250	<1,250
Length dry season (months) P < 1/2PET	0-1	1-2	2-3	3-4	>4
Mean annual max. temp. (°C)	>29	29-27	27-24	24-22	<22
Average daily min. temp coldest month (°C)	>20	20-18	18-16	16-14	<14
Mean annual temp. (°C)	>25	25-22	22-20	20-18	<18

Source: Sys et al. (1993).

Increased precipitation also favours oil palm productivity unless it leads to flooding, whereby prolonged flooding can lead to death of the oil palms (PORIM 1994). The factors most likely to affect oil palm productivity negatively will be an increase in both dry weather and the length of dry spells. Dry and cloudy periods generally affect growth through changes in physiological performance and subsequently yield reduction. However, the effect on yield reduction may not be immediate, it may be delayed up to two or more years after the event.

Stomatal conductance is an important determinant of crop water use, photosynthesis and productivity, as well as being a major factor controlling plant water status (Jones and Higgs 1989). Decreased stomatal conductance during the drought limits the amount of carbon dioxide fixation for photosynthesis into the leaves of oil palm (Smith 1989; Potulski 1990) and in this way is likely to contribute to the observed seasonal yield cycles. The most important factor controlling seasonal and diurnal variations in stomatal conductance is soil water content, followed by leaf temperature and leaf to air saturation vapour pressure deficit (Potulski 1990). High leaf temperature above 35°C may inhibit photosynthetic rates and indirectly cause a stomatal closure in oil palm (Potulski 1990). There is an overall reduction in stomatal conductance as well as an increase in the magnitude of the stomatal closing response to an increase in leaf to air saturation vapour pressure deficit under reduced soil water conditions (Potulski 1990). Although stomatal closure helps to preserve a limited water supply by reducing transpirational water loss from leaves it also limits the rate of photosynthesis (Corley 1976; Smith 1989; Potulski 1990), and this may result in the reduction of carbohydrate availability for flower and fruit formation. It was observed that the total daily photosynthetic rate was reduced by 30% in the dry season as compared to wet season (Potulski 1990). The reduced capacity in photosynthetic assimilation may be a factor contributing to the annual yield cycles (Corley

1976) and the occurrence of stomatal closure for only 40 days in a year may reduce bunch yield by 10% per year (Corley1973).

Variation in seasonal water availability is reflected in seasonal bunch yield pattern. Short-term symptoms of drought are a decrease in stomatal conductance, spear leaf growth and an increase in leaf senescence and fruit abortion (Potulski 1990). A long term effect of drought on the other hand occurs through an increase in the male:female flower ratio (Corley 1976), through the abortion of immature fruit and the formation of smaller bunches with subsequently lower yields. Good irrigation largely alleviates the effects of drought by keeping stomatal conductance and photosynthetic rates relatively high and maintaining lower leaf temperature through higher evapotranspiration rates (Potulski 1990).

The areas most affected will be oil palm grown in agroclimatological region A, a region defined by Yew et al. (1987) to have 3 to 5 months of distinct dry months plus 1 to 4 months with frequent moisture stress days. This region encompasses Perlis, parts of Kedah, Kelantan and Terengganu. Currently, oil palm is not cultivated in this region. Oil palm is currently planted in agroclimatological region B, i.e. a region with 2 distinct dry months plus 1 to 2 months with frequent moisture stress days. This region is currently found to be marginal for oil palm cultivation. In terms of production, oil palm yields in this region, consisting of parts of Kelantan, Terengganu, Pahang, Johor, Perak, Kedah, Negeri Sembilan and Melaka, will be most severely affected by the climatic variability.

It is extrapolated that there will be about 30% reduction in yield potential as affected by climate variability due to temperature and precipitation extremes (Table 4.6). The results also indicate an increase in yield of about 6% is possible with 7% increase in rainfall and 1.4°C increase in temperature above the current temperature.

Table 4.6 Projected oil palm yield (tons/ha/yr) with climate variability.

CO_2 (ppm)	400	400	400
Temp (°C)	0.3	0.85	1.4
Rainfall change			
+14%	21.5 (-2.3%)	21.5 (-2.3%)	22.0 (0%)
+7%	23.0 (4.5%)	23.0 (4.5%)	23.25 (5.7%)
+0.40%	22.5 (2.3%)	22.5 (2.3%)	22.75 (3.4%)
0 (current)	**22.0**	**22.0**	**22.0**
-0.40%	22.0 (0%)	22.0 (0%)	22.0 (0%)
-7%	17.6 (-20%)	17.6 (-20%)	17.0 (-22.&%)
-14%	15.4 (-30%)	15.4 (-30%)	15.4 (-30%)

Source: Krishnan et al. (2000).

The above table indicates the projected potential yield (percentage changes) in oil palm under scenarios of temperature and precipitation extremes. The oil palm yield is expected to increase from 2.3% to 5.7% (from current yield of 22 to 22.5 and 23.25 tons/ha/yr respectively) under conditions of greater rainfall (an increase of rainfall from 0.4 to 7%). However, under limited water conditions such as a reduction of rainfall as much as 14%, the reduction in yield could be as high as 30%. The magnitude of potential yield reduction due to reduction in rainfall is similar under all conditions of temperature increase. However, there is no change in oil palm yield due to a small increase in temperature.

4.6.3 Rubber

4.6.3.1 Climatic requirements

The rubber tree is originally from the tropical rain forest. Therefore the temperature range for growth is between 22 and 35°C. Rubber trees prefer a tropical climate. According to Yew and Sys (1990), the climatic features suitable for rubber cultivation include high mean daily air temperature of 25-28°C, high rainfall exceeding 2000 mm/year and yet not interfering with tapping and latex collection (Table 4.7). The rainfall must be evenly distributed such that rubber does not encounter dry seasons exceeding one month. The rubber tree is also sun-loving, preferring areas that have at least 2,100 hours of sunshine per year.

4.6.3.2 Effects of climatic change and variability

Throughout the lowlands of Peninsular Malaysia, the annual mean temperatures vary within 26.7°C ± 1.7°C (Dale 1963). The impact of a temperature rise ranging from 1 to 4.5°C on rubber cultivation will be nil at 1°C rise, slight if temperature increases by 3.5°C and moderate if temperature increases by 4.5°C (Yew 1990). No in-depth study has been made on the impact of temperature change alone on rubber growth and productivity. It is, however, known that, when higher temperatures occur in combination with other climatic parameters, more months with moisture stress or more dry months will result. In fact, an increase in both the probability of occurrence of dry weather and the increased length of dry spells is predicted. Based on observations of the effects of the drought in 1990 on rubber productivity, a 3% to 15% crop decrease due to drought conditions can be expected if mean annual temperatures increase to 30 - 31°C (Yew 1990). The degree of yield decrease will be dependent on clonal resistance, i.e. some clones are more susceptible to drought than other clones.

The higher the total annual rainfall in an area, the lower the mean yield of rubber for the year and vice versa. The low yield may be due to loss of crop due to interference of morning rains or reduction in yield due to leaf diseases. The high yield may be related to the formation of good tree canopy after a dry spell and low incidence of leaf diseases due to the dry microenvironment (Mohamad and Yew 1991).

Latex being predominantly watery, its flow from the tree is very much influenced by the plant water relations. Latex yield and the pattern of latex flow are remarkably altered by soil moisture. The duration of flow as well as the amount of latex is reduced during drought (Sethuraj and Raghavendra 1987). Latex yield per tree is generally influenced by initial flow rate of tapping, the length of the tapping cut, dry rubber content and plugging index (restriction of the latex flow due to a physical plug forming near the cut surface of the latex vessels). All these factors are influenced by external and internal factors. The turgor pressure affects the initial flow rate at the time of tapping. Under severe drought conditions turgor pressure is reduced, which will markedly reduce the latex flow. Changes in water vapour deficit in the air may also affect tapping initial flow rate.

Wintering is a phenomenon where rubber trees shed their leaves. This occurs during the dry spell, which lasts a few days or up to 4 to 5 months. Wintering is beneficial in the cultivation of rubber. During defoliation, rubber trees undergo a partial rest. Biomass production is much reduced and tapping the trees may have to be stopped if the dry spell is too long. Higher yield is usually obtained after defoliation as a result of good canopy formation. Rubber is grown on 1.8 million ha of land in Peninsular Malaysia. The states of Perlis, parts of Kedah, Kelantan and Terengganu are considered to be the drier regions for rubber cultivation in Peninsular Malaysia (Yew et al. 1987; Abu et al. 1990). Climatic variability such as prolonged drought and high temperature in these areas may drastically affect the yield and livelihood of smallholders.

While a decrease in rainfall can lead to drought conditions, an increase of rainfall can cause a loss of crop due to rainfall interference with tapping; yield losses reported range between 13% and 30% (Yew 1982) giving a mean loss of about 21%. Currently and in the future, long flow systems of exploitation, e.g. RRIMFLOW (Sivakumaran 1997) and REACTORRIM (Ahmad Zarin 1997) are recommended in the rubber industry.

Although Peninsular Malaysia has an apparent total potential land area of 3.8 million hectares that may be cultivated with rubber (Abu et al. 1990), it is unlikely that any new land will be planted with rubber, given the more attractive returns and lower labour requirements for oil palm cultivation. Based on the assumptions that the present land area of rubber is not converted into other land use e.g. oil palm, the predicted changes in yield potential, as affected by climate variability are presented in Table 4.8. Predictions are based on the following assumptions:

- National average yields are assumed to be at 1,600 kg/ha/yr in year 2020, 1,800 kg/ha/yr in year 2,040 and 2,000 kg/ha/yr in 2060. Yields reflect technological advancement and planting materials.
- Carbon dioxide is not limiting at the projected concentrations.
- Evaluation of temperature and rainfall effects follows the system of Yew and Sys (1990).
- Effect of drought and rainfall interference with tapping is also based on experiences of Yew (1982), Yew (1982) and Dahlan and Yahya (1979).
- Current mean temperature = 27.7 °C.
- Current mean rainfall = 2,157 mm/year.
- It is assumed that there are no effective methods available to prevent rainfall interference with tapping

Table 4.7 Climatic requirements for rubber cultivation.

Climatic Characteristic	Degree of Limitation				
	None	Slight	Moderate	Severe	Very Severe
Mean daily air temperature (°C)	28-25	24-22 29-30	21-20 31-32	19-18 33-34	<18 >34
Mean daily maximum air temp. (°C)	34-29	28-27 >34	26-24	23-22	<22
Mean daily minimum air temp. (°C)	>20	20-19	18-17	16-17	<16
Mean annual rainfall (mm)	>2000	2000-1750	1749-1500	1499-1250	<1250
Expected total rain interference (days/yr)	0-30	31-60	61-90	>90	
Sunshine length (hours/yr)	>2100	2100-1800	1799-1400	1399-1000	<1000
Maximum wind speed (m/see)	0-7	8-14	15-21	22-30	>30
Mean annual relative humidity	<80	80-100	80-100	80-100	80-100
Length of dry season (months/yr)	0-1	2-3	4	5-6	>6

Source: Yew and Sys (1990).

Table 4.8 Projected rubber yield (kg/ha/yr) with climatic variability.

CO_2 (ppm)	400	400	400
Temp (°C)	0.3	0.85	1.4
Rainfall			
+14%	1,264 (21%)	1,264 (-21%0	1,232 (-23%)
+7%	1,440 (-10%)	1,440 (-10%)	1,424 (-11%)
+0.40%	1,600 (0%)	1,600 (0%)	1,600 (0%)
0%	**1,600**	**1,600**	**1,600**
-0.40%	1,600 (0%)	1,600 (0%)	1,600 (0%)
-7%	1,552 (-3%)	1,552 (-3%)	1,536 (-4%)
-14%	1,456 (-9%)	1,456 (-9%)	1,440 (-10%)

Source: Krishnan et al. (2000).

The above table indicates the projected potential yield (percentage changes) in rubber under scenarios of temperature and precipitation extremes. Similarly with rice, there is a reduction in yield as the result of both increase or decrease in total rainfall from the present rainfall requirement in rubber. The rubber yield is expected to decline from 3 to 10% from the current potential yield of 1,600 kg/ha/yr as the result of 7 to 14% reduction in current rainfall. However, excessive rainfall (an increase of 7 to 14%) may further reduce rubber potential yield as much as 23% (1,232 kg/ha/yr). This substantial reduction in yield may be due to tapping interference during rainy days. The magnitude of potential yield reduction due to reduction in rainfall is similar under all conditions of temperature increase. However, there is no change in rubber yield due to a small increase in temperature.

The results indicate that there will be about 9% and 12.5% reduction in yield as the result of water shortage and water shortage in combination with an increase in temperature, respectively. An increase in rainfall as much as 14% will further reduce rubber yield as much as 21%.

4.6.4 Sugarcane

4.6.4.1 Climatic requirements

Sugarcane is essentially a tropical species adapted to a warm, sunny and moist growing season. For a successful crop, precipitation that exceeds 1300mm/yr with a total rainfall of 110-180 mm/month is needed during the growing period (Table 4.9). Growth is optimal between 24^{o}C and 32^{o}C, and becomes minimal when temperatures fall below 20^{o}C or rise above 34^{o}C (Sys 1993).

4.6.4.2 Effects of climatic change and variability

Being a C_4 species, sugarcane's photosynthetic rate increases linearly with the increase in the irradiance level (Nickell 1974). Solar radiation is important in tiller or shoot production; a severe decrease in radiation, e.g., 15-20%, significantly reduces the yield.

Sugarcane is well known for high water requirement for growth (Nickell 1969). During early stages of development, much water is needed for the development of young buds as well formation of a dense stand of canes (Gill 1962). Drought may affect photosynthesis as much as 25% when soil water is reduced to the permanent wilting point. However, a dry period is needed during the cane ripening stage. Water availability has a pronounced effect on sucrose storage. In general, dry weather is preferred during the last 6-8 weeks prior to harvest (Gascho and Shih 1982). The dry weather also helps concentrate sucrose by evaporating water from the leaf surface.

Within the optimal growing temperature, a positive linear relationship exists between growth and temperature.

Table 4.9 Climate requirements for sugarcane.

Climate Characteristic	Limitations				
	None	Slight	Moderate	Severe	Very Severe
10 days rainfall (mm)	>70	70-60	60-50	50-30	<30
Mean day temp. at	28-30	30-32	32-34	34-35	>35
germination (°C)	28-26	26-24	24-20	20-16	<16
Mean day temp. for	27-28	28-32	32-35	>35	-
tillage stage (°C)	27-26	26-20	20-16	16-8	<8
Mean day temp. for	26-25	25-22	22-20	20-18	<18
vegetative stage (°C)	26-27	27-32	32-35	>35	-
(Tmax-Tmin)/Tmean maturation stage	>0.5	0.5-0.45	0.45-0.4	0.4-0.3	<0.3
Sunshine: hours/year	>2,200	2,200-1,800	1,800-1,400	1,400-1,200	<1,200
Mean annual n/N	>0.5	0.5-0.4	0.4-0.3	0.3-0.2	<0.2
Relative humidity of maturation stage (%)	0-60	60-70	>70	-	-

Source: Sys et al. (1993).

Note: Tmax = maximum temperature;
Tmin = minimum temperature;
Tmean = mean temperature;
Mean annual n/N = (n= actual hours of bright sunshine)/(N= astronomically possible hours of bright sunshine=daylength).

4.6.5 Fruit trees

4.6.5.1 Climatic requirements

Perennial fruit trees such as durian, rambutan, mango and mangosteen require annual precipitation of greater than 2,000 mm/yr. The optimal growth temperature is between 22 and 28°C. Long and even distribution of rainfall is ideal for good growth performance. The climatic requirements for selected fruit trees are given in Table 4.10.

4.6.5.2 Effects of climatic change and variability

Most tropical fruit trees require water during the early stage of growth, particularly from field planting to first flowering. Slow vegetative growth is usually associated with lack of sufficient water during field establishment. The requirement of a dry period for good flowering has been observed in durian and mango. However, these trees cannot tolerate a drought period for more than three months. Rain and cloudy weather at the flowering stage will affect fruit setting adversely.

A drought can result in reduced tree fruit production for several years, assuming that the trees survive the drought. With fruit trees, the flower buds for the following season are initiated during the previous season, and prolonged drought can inhibit the initiation of flowers for the next season. A drought can also reduce the quantity and quality of the current season's fruit crop as well.

To better understand the effect of drought on fruit production it is necessary to understand the fruit's seasonal moisture requirements and to understand how drought affects fruit growth and development. Fruit trees have different patterns of shoot and fruit growth, so drought during different times of the season will result in varying responses. Growth of all plant organs is dependent on an adequate supply of carbohydrates. Carbohydrates, the main food source in trees, are produced in the leaves during photosynthesis. Photosynthesis requires sunlight, carbon dioxide, and water. Stomates allow carbon dioxide to enter the leaf and water vapour to exit. Maximum photosynthetic rates and, therefore, maximum carbohydrate production occur when the stomates are open. When plants experience drought stress, the stomates close to conserve water and photosynthesis and carbohydrate production are seriously reduced. Under drought conditions or high temperature stress, leaf photosynthetic rates may drop to 20% of normal. Therefore, avoiding drought stress with irrigation will result in greater production of carbohydrates for increased tree and fruit growth.

Table 4.10 Summary of climatic requirements of selected fruit trees.

	Crop	Temperature (°C)	Water/Rainfall Requirements (mm/yr)	Suitability Status (Moist months/year)			Moisture Sensitive Period	Remarks
				Best	Suitable	Marginal		
1	Durian (*Durio zibethinus*)	22-28	2,000 or more	5-6	7-9	10-12	-	Long and even rain distribution. Cannot tolerate more than 3 mths. intense dry period except with irrigation or high water table. No water logging.
2	Mango	24-27	760 - 3,800	5	5	1-5	Establishment, blooming, and fruiting.	Rainfall distribution more important than quantity. Dry period before flowering. Rain and cloudy weather at flowering adverse to fruit setting. Heavy rains at ripening also cause considerable damage.
			mm rain/mth (20th. Percentile rain)	<60	<60	60-120		
			rain days/mth	<10	10-12	12-15		
4	Starfruit	22-28		10-12	7-9	5-6		
3	Mangosteen (*Garcinia mangostana*)	20-30	2,500 or more	10-12	7-9	5-6	First few of growth especially dry season	Requires high rainfall areas. Water table about 2 m below soil surface ideal. Irrigation needed in dry areas.
4	Banana	15-35 25-30 (optimum)	100 - 150 mm/mo except in very porous soils	10-12	7-9	5-6	All stages	Serious water stress if rain less than 50 mm in any month and no irrigation or deep water table.
5	Papaya	21-33	1,200 or more	10-12	7-9	5-6	Flowering	Very sensitive to even short periods of flooding. Irrigation helpful in dry areas.

Source: Anon 1993.

4.6.6 Vegetables

4.6.6.1 Climatic requirements

The general climatic requirements for selected vegetables are given in Table 4.11. Vegetable crop water requirements range from about 15 to 35 mm/week or 300 to 500 mm of water per season (Anon 1993). Precise irrigation requirements can be predicted based on crop water use and effective precipitation values. The amount of irrigation water can also be based on evapotranspiration crop coefficients, which vary according to growth stage. In capsicum, these coefficients are 0.3, 0.6, 0.95, 0.85 and 0.80, while for long bean they are, 0.3, 0.65, 0.95, 0.9 and 0.85 for initial, crop development, mid-season, late season and harvest stages respectively (Doorenbos and Kassam 1979).

4.6.6.2 Effects of climatic change and variability

Lack of water influences crop growth in many ways. The effect depends on the severity, duration, and time of stress in relation to the stage of growth. Nearly all vegetable crops are sensitive to drought during two periods: during harvest and two to three weeks before harvest. Although all vegetables benefit from irrigation, each class responds differently.

Many leafy vegetables (cabbage and various brassicas) are generally planted at or near field capacity. Being shallow rooted, these crops benefit from frequent irrigation throughout the season. As leaf expansion relates closely to water availability, these crops, especially cabbage, cauliflower and broccoli, are particularly sensitive to drought stress during the period of head formation through harvest. Over watering or irregular watering can result in burst heads. Broccoli and cauliflower are sensitive to drought stress at all stages of growth, responding to drought with reduced growth and premature heading.

Fruit vegetables (cucumbers, beans, capsicum and tomatoes) are most sensitive to drought stress at flowering and fruit development stages. Fruit set on these crops can be seriously reduced if water becomes limited. An adequate supply of water during the period of fruit enlargement can reduce the incidence of fruit cracking.

Plant growth stage also influences the susceptibility of crops to drought stress. Irrigation is especially useful when establishing newly seeded or transplanted crops. Irrigation after transplanting can significantly increase the plant survival rate, especially when soil moisture is marginal and the evapotranspiration rate is high. Irrigation can also increase the uniformity of emergence and final stand of seeded crops.

The periods of crop growth when an adequate supply of water is critical for high-quality vegetable production are shown in Table 4.11 and 4.12.

Severe drought conditions have adverse effects on the yield and quality of a wide range of vegetable crops. Vegetable production involves higher costs than many other crops. Among the reasons are volatile market risk and the need for optimum levels of appearance, consistent supplies and qualities in the marketplace. Moreover, many vegetable crops have high water requirements.

Irrigation planning and management as well as cultural practices that conserve soil moisture and allow plants to use water efficiently are generally critical for profitable vegetable production especially under drought conditions.

Supplemental irrigation is beneficial in most years since rainfall is rarely uniformly distributed, even in years with above-average precipitation. Moisture deficiencies occurring early in the crop cycle may delay maturity and reduce yields. Shortages later in the season often lower quality as well as yields. However, over-irrigating, especially late in the season, can reduce quality and postharvest life of the crop.

Table 4.11 Climate requirements for selected vegetables.

	Crop	Temperature Requirements (°C)	Water/Rainfall Requirements	Moisture Sensitive Period	Remarks
1	Cabbage	20-30	15 - 35 mm/week	Head formation; enlargement.	Requires moderately high soil moisture throughout growth and adequate drainage.
2	Common bean	20-30	25 mm/ week	Flowering and fruit development	Excessive or too little moisture may cause blossom and pod drop. Too dry soil needs irrigation before planting.
3	Chilli (capsicum)	16-33	800-900 mm/crop	Whole growing period, especially before and at flowering	Grows best with moderate rain or under dry conditions with irrigation. No water logging.
4	Cucumber	18-24 35 (max)	300 mm/crop	Flowering, particularly at full bloom	Drought during flowering may result in deformed, nonviable pollen grains and may damage the gynoecium.
5	Okra	20-30 35 (max)	300 mm/ crop		Some varieties sensitive to excessive soil moisture.
6	Cauliflower	20-30	15 - 35 mm/wk	Early seeding stage; during rapid growth of curd.	Requires plentiful supply of water throughout development of crop for maximum yield.
7	Eggplant	25-35	340- 515 mm/ crop	-	Can tolerate drought and more excessive rainfall.

Source: Anon 1993.

Table 4.12 Critical periods of water required by crops.

Crop	Critical Period
Leafy vegetables	Continuous
Capsicum	Flowering and fruit development
Beans	Flowering, pollination and pod development
Broccoli	Head development
Cabbage	Head development
Cauliflower	Head development
Cucumbers	Flowering and fruit development
Eggplants	Flowering and fruit development
Tomatoes	Early flowering, fruit set, and enlargement

Source: Salter and Goode (1967).

The crop water requirement, termed evapotranspiration, is equal to the quantity of water lost from the plant (transpiration) plus that lost from the soil by surface evaporation. The evapotranspiration rate is important in effectively scheduling irrigation. Numerous factors must be considered when estimating evapotranspiration, but the amount of solar radiation, which provides the energy to evaporate moisture from the soil and plant surfaces, is the major factor. Other factors include day length, air temperature, wind speed, and humidity level.

Plant factors that affect the evapotranspiration rate are crop species, canopy size and shape, leaf size, shape, and orientation, plant population, rooting depth, and stage of growth and development of the crop. The plant canopy size and shape influence light absorption, reflection, and the rate at which water evaporates from the soil. Leaf architecture affects the transpiration rate from individual leaves. Rooting depth varies with crop species and may be affected by compaction or hardpans that may exist. Rooting depth determines the volume of soil from which the crop can draw water and is important when determining the depth to which the soil must be moistened when irrigating.

Cultural practices also influence evapotranspiration. Cultivation, mulching, weed growth, and method of irrigation are factors to consider. Cultivation generally does not reduce evaporation significantly, but if crop roots are pruned by cultivating too close, water uptake and thus transpiration may be reduced. Shallow cultivation may help eliminate soil crusts and therefore improve water infiltration. Weeds compete with the crop for water and increase the amount lost through transpiration. Sprinkler irrigation wets the entire crop area and thus results in a greater evaporation loss than does drip irrigation, which wets only the area in the immediate vicinity of the plants.

Soil factors must also be considered. Soils with high water-holding capacity require less frequent irrigation than those with low water-holding capacity. However, when soils are irrigated less frequently, a greater amount of water must be applied per application. Another soil factor that influences irrigation practices is the infiltration rate. Water should not be applied at a rate greater than the rate at which the soil can absorb it.

5. Macro Effects and Impacts

This chapter is devoted to analyzing the effects and impacts of the El Nino related weather conditions. The analyses cover most of the important economic and socio-economic crops and commodities in Malaysia, including oil palm, rubber, rice, vegetables, fruits, fisheries including aquaculture and also selected livestock that are of economic importance.

The first section of this chapter briefly describes the analytical approach for assessing the effects of the El Nino on the specific commodities. This is followed by sections on the specific commodities, which mainly comprise a brief background on the commodity industry and the analysis on the effects and impacts of the major El Nino episodes that have taken place in Malaysia on the performance of commodities.

5.1 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 yield function was used to obtain crop response relationships to a number of variables that were hypothesized to influence crop yield 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 in the previous chapter. This method was applied to Malaysia's three most important crops viz. oil palm, rubber and rice.

The specified functional form for the yield function for the three crops is as follows:

$$LnY_t = f(RF_t, TSP_t, TEMP_t, YEAR_t)$$

where:

LnY_t = natural log of yield in year t,

RF_t = average monthly rainfall in year t,

TSP_t = average monthly total suspended particulates in the atmosphere in year t,

Temp = average monthly temperature in year t, and

$YEAR_t$ = time trend variable as a proxy for technological advancements

A dummy variable (DUM) and dummy interactive variables were introduced into the models for the years with major El Nino episodes to determine if there were any significant differences between the "El Nino years" (EY) and the "non-El Nino years" (NEY). For the oil palm function, the variables were lagged for one year (t-1) to reflect the lagged effect of the variables on the performance of a perennial crop like oil palm.

For the other commodities, a more qualitative approach was used. The first was by using graphical exposition, where variables were plotted with each other to observe if there were any obvious relationship between commodity performance and the El Nino weather variables such as rainfall, TSP and temperature. The second method was 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.

5.2 Oil palm

5.2.1 Background of the industry

Malaysia is the world's largest producer and exporter of palm oil, accounting for more than 50% of world production and more than 60% of world exports. The palm oil industry is the single largest agricultural entity in Malaysia. It is the leading commodity export earner with total exports amounting to about RM 16 billion in 1999. This represents more than 30% of all agricultural exports. Currently, the cultivation of oil palm in the country covers an area of 3.4 million hectares accounting for 54% of the overall agricultural land use. Of this total, more than 40% is under smallholders, who consist of organized land schemes and independent smallholders (Table 5.1). The remaining area belongs to large private estates and corporations. In total, about 250,000 families in government land schemes and independent smallholdings as well as 80,000 workers in the private estates of Peninsular Malaysia are dependent on this industry for their livelihood.

Table 5.1 Distribution of oil palm areas (hectares).

Category	1999		2000	
	Hectares	%	Hectares	%
Private Estates	1,942,452	58.62	1,993,292	58.92
Public Sector				
FELDA	674,948	20.37	685,520	20.26
FELCRA	132,354	3.99	134,357	3.97
RISDA	41,561	1.25	37,011	1.10
State Schemes	235,565	7.11	242,002	7.15
Independent Smallholders	286,513	8.65	290,818	8.60
TOTAL	3,313,393	100	3,383,000	100

Source: Malaysian Palm Oil Board (2001).

Apart from the upstream end, the downstream and supporting industries in palm oil have evolved into a gigantic business. The range of downstream activities includes milling, refining, manufacturing of cooking oil, shortening, margarine, and confectionery fat. There are also non-food product industries such as oleochemical derivatives including fatty acids, glycerine, methyl esters, and soaps. The palm oil industry also has created new and expanding opportunities for the services and input industries including chemicals and fertilizers, transportation, insurance, packaging, machinery and equipment as well industrial materials.

The palm oil industrial cluster is therefore a multi-billion ringgit cluster and its contribution to the national economy is enormous. Hence an external disturbance such as weather variability resulting from the El Nino that has the potential to negatively effect upstream production can result in a string of negative reactions throughout the cluster. This can mean billion ringgit losses to the nation, from the small farmer and millers to the manufacturers, transporters and other service providers.

5.2.2 Effects of El Nino on oil palm

Figure 5.1 shows the yield pattern of oil palm and average rainfall pattern for the 1980 – 1999 period. The points E are the years with major El Nino episodes i.e. in 1981, 1982, 1990, 1997 and 1998. The El Nino years identified here for the purpose of analyses of impacts are based on years that exhibited abnormal mean yearly values of of El Nino related variables such as relatively high temperatures, low rainfall and high total suspended particulates in the atmosphere. This categorization may slightly differ with the officially declared El Nino years by the government as described in the preceding chapters. These El Nino officially declared years were based on intermittant seasonal El Nino episodes within a particular year. As such mean yearly data of some of these years do not reflect the abnormality condition of low rainfall, high temperature and high particultaes. Therefore the use of the officially declared El Nino years to study the impacts of El Nino related phenomena will be biased. Since oil palm is a perennial crop, it is expected that the real effect on crop yield would only come at least one year after any abnormal weather variability. It can be seen from the graph that in the first episode in 1981 and 1982, where rainfall was lower than normal, the yield of palm oil stagnated in 1982 and dipped below 3.5 tons/per hectare in 1983 (point a). Similar trends can be observed for the 1990 and 1997 as well as the 1998 episodes. After both El Nino episodes, the average yield of oil palm dropped consistently to a level substantially lower than the few years before (points b and c). The most severe El Nino episode, the 1997/1998 episode saw the oil palm yield dipping to just over 3 tons hectare, the lowest in 20 years.

Figure 5.2 also shows that some association existed between TSP and palm oil yield. Yields in most cases decreased when TSP increased. This was obvious during the El Nino episodes (points E) where their TSPs were high resulting in haze. Theoretically, this haze prevents plants from fully photosynthesizing due to reduced sunlight. This is indicated by points a, b and c in the figure.

Figure 5.1 Oil palm yields and rainfall pattern, 1980 – 1999.

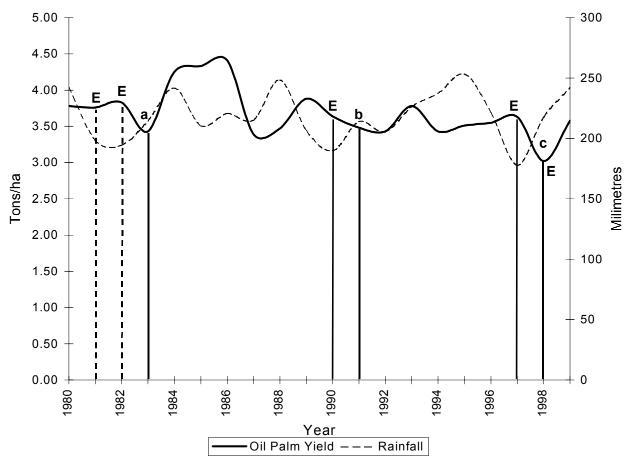
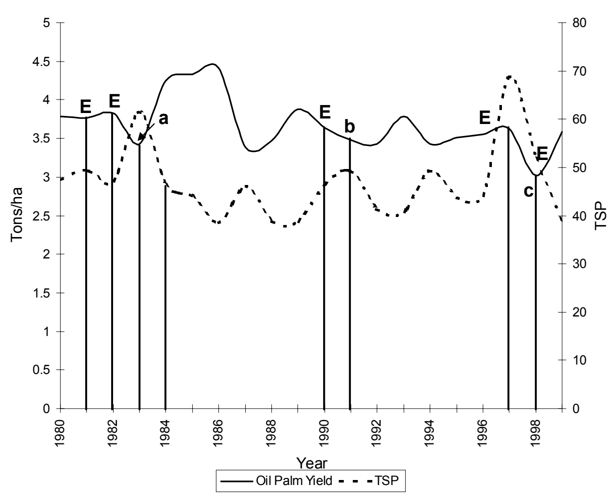


Figure 5.2 Oil palm yields and TSP pattern, 1980 – 1999.



To give a quantitative estimate of the effect of the El Nino related weather condition, a method outlined by Gommes (1998) was used. In yield or production national time series data, the maximum yield/production value P_m in a five-year interval from Y_{t-2} to Y_{t+2} was taken. The difference between the production P_t of the year Y_t was then expressed as a percentage loss which is equal to $(P_m - P_t)/P_m \times 100$. In this method, it was assumed that no significant technological progress took place during the five-year interval. Thus, any changes in yields can be attributed to weather variability.

The results of the analysis for oil palm are tabulated in Table 5.2. Results of the analysis reveal that the palm oil industry, indeed, did suffer significant losses from weather variability. The 1981 and 1982 episodes of El Nino for example resulted in an almost 21% loss the following year, while the 1990 episode resulted in a more than 10% yield loss in 1991. The most severe El Nino episode of 1997 also resulted in the highest yield loss of 16.8%. Based on nominal prices of palm oil for the respective years, the gross total loss for the four major episodes amounted to an astounding RM 4.7 billion (Table 5.3). 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 results also show 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 the 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 5.4). Even after subtracting for all other vagaries the damage from the El Nino still amounted to almost 10%. By subtracting the mean NEY loss from the loss in an EY, the net loss from the El Nino could be obtained for the year. This is shown in Table 5.5. Based on this estimate, the total net loss resulting from the El Nino was RM 2.65 billion.

To further analyze this phenomena, a national yield function for oil palm was estimated (Appendix 1). The results of the estimation showed that the dummy variable which was introduced for all the years with major El Nino episodes was statistically significant at the 5% probability level. TSP was also significant, indicating that the haze did significantly influence oil palm yields. The regression analysis indicated that El Nino had significant effects on oil palm yields. This analysis further strengthened the argument that the net loss of RM 2.65 billion to the palm oil industry can be attributed to the El Nino.

Table 5.2 Estimated loss of oil palm yield due to weather variability, Malaysia, 1980 - 1999.

Year	Yield (t/ha)	Five Year Moving Maximum (t/ha)	Difference	% loss
1980	3.78	-	-	-
1981	3.76	4.25	0.49	11.53[1/]
1982	3.86	4.25	0.39	9.18[1/(2)]
1983	3.43	4.33	0.90	20.78[(2)]
1984	4.25	4.41	0.16	3.63
1985	4.33	4.41	0.08	1.81
1986	4.41	4.41	0.00	0.00
1987	3.39	4.41	1.02	23.13
1988	3.49	4.41	0.92	20.86
1989	3.88	3.88	0.00	0.00
1990	3.64	3.88	0.24	6.16[1/]
1991	3.48	3.88	0.40	10.30
1992	3.43	3.78	0.35	9.26
1993	3.78	3.78	0.00	0.00
1994	3.43	3.78	0.35	9.26
1995	3.51	3.78	0.27	7.14
1996	3.55	3.63	0.08	2.20
1997	3.63	3.63	0.00	0.00[1/]
1998	3.02	3.63	0.61	16.80[(2)]
1999	3.58	-	-	-

Note: [1] Year with major El Nino episodes.
[2] Affected years.

Table 5.3 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/ton (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

Table 5.4 Mean yield losses for EY and NEY.

Item	Mean Yield Loss (%)
Mean yield loss for NEY	6.78
Mean yield loss for EY	14.57
Net El Nino effects	-7.49

Table 5.5 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/ton (RM/ton)	Loss (RM million)
1982	2.90	3,510.92	3,595.78	84.26	84.26	69.85
1983	14.00	3,016.48	3,438.79	422.31	422.31	418.51
1991	3.52	6,141.35	6,357.53	216.18	216.18	180.83
1998	10.02	8,319.68	9,153.31	833.63	2,377.5	1,981.96
					Total net loss	2,651.15

5.3 Rubber

5.3.1 Background of the industry

Rubber was the number one crop of the country for many decades since independence. In the 1950s, commercial agriculture in Malaysia was synonymous with rubber. In those days, there were already 1.5 million hectares of rubber, and expansion was headed by the fast expanding world automobile and transport industry (Sekhar 2000). However, the advent of synthetic rubber provided a cheaper substitute for natural rubber. This resulted in falling prices of natural rubber and drastic reductions in the profitability of the industry. Rubber areas in Malaysia steadily declined over the years, most of them replaced with oil palm. From its peak of over 2 million hectares in 1970, rubber area declined to 1.43 million hectares by 2000 (Table 5.6). Currently, of the total 1.4 million hectares, over 1.2 million hectares or 86% are under smallholders with the remaining belonging to larger private estates.

Table 5.6 Area under rubber, Malaysia, 1970 – 2000.

Year	Area ('000 hectares)
1970	2,181.8
1985	1,948.7
1990	1,836.7
1991	1,818.7
1992	1,792.4
1993	1,762.5
1994	1,737.9
1995	1,688.8
1996	1,644.4
1997	1,624.2
1998	1,620.2
1999	1,464.8
2000	1,430.7

Sources: Economic Planing Unit, Malaysia (1970); Ministry of Agriculture, Malaysia, (1999); Malaysia Rubber Board (2001).

Nevertheless, despite its declining sectional importance, the rubber industry continues to significantly contribute to the overall domestic economy. About 400,000 farm families and more than 53,000 estate workers are still heavily involved in natural rubber production (Ministry of Agriculture 1999). Exports of natural rubber alone in 1999 were more than RM 2.3 billion, while the exports of natural rubber together with all other rubber-based products were estimated in excess of RM 8 billion.

5.3.2 Effects of El Nino on rubber

Figures 5.3 and 5.4 show the rainfall and TSP patterns with rubber yield pattern respectively for the 1980 – 1999 period. It appears that there was no distinguishable associationship between rainfall and rubber yield. During the early part of the period, yield increased as rainfall increased. However, after 1989 yields started to steadily decline irrespective of rainfall. Significant negative yield movements can be detected for the 1990 episode. However, based on this observation alone, the relationship cannot be established. Undiscerned patterns are also observed for rubber yields and TSP. Yields increase and decline irrespective of TSP levels (Figure 5.4).

Figure 5.3 Rubber yields and rainfall pattern, 1980 – 1999.

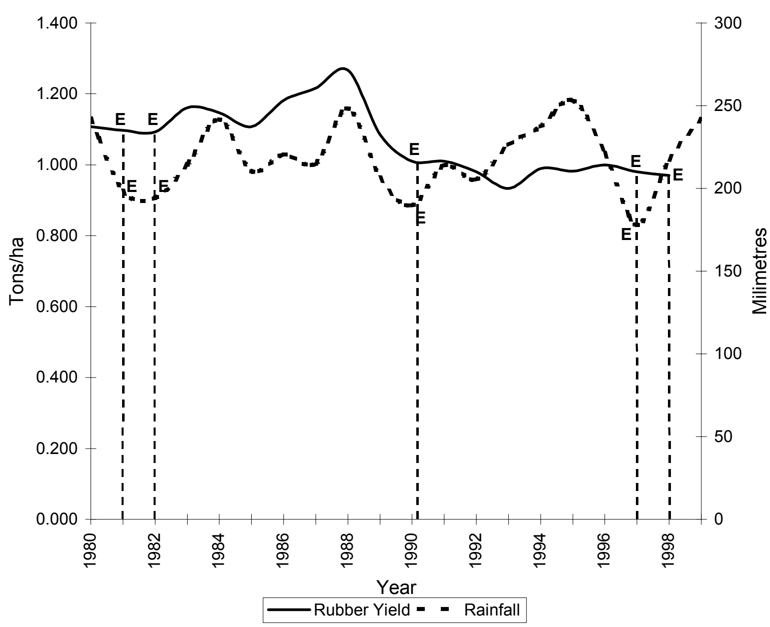
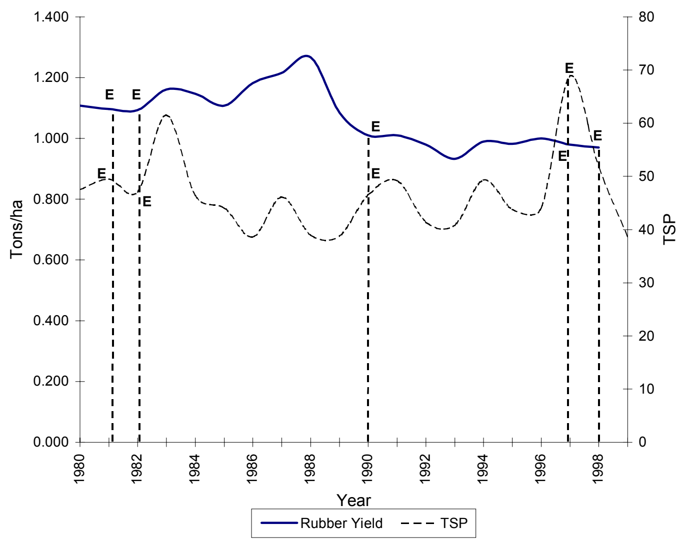


Figure 5.4 Rubber yields and TSP pattern, 1980 – 1999.



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 results can be seen in Table 5.7. The percentage losses from weather variability ranged between 0 to 20.28%. Average yield loss for the EY was 7.33%, while average yield loss for the NEY was 4.33%. Therefore, the net El Nino affect was estimated to be 3.00%. Although the percentage loss could be considered small, the value of the loss can be significant due to the size of production. In Table 5.8, the magnitude of loss for each of the El Nino years with negative net loss from El Nino was computed. Total losses were estimated to be RM 356.75 million.

Table 5.7 Estimated loss of rubber yield due to weather variability, Malaysia, 1980 – 1999.

Year	Yield (t/ha)	Five Year Moving Maximum	Difference	% Loss
1980	1.108	-	-	-
1981	1.097	1.161	0.064	5.51[1]
1982	1.093	1.161	0.068	5.86[1]
1983	1.161	1.161	0.000	0.00
1984	1.147	1.182	0.035	2.96
1985	1.108	1.216	0.108	8.88
1986	1.182	1.267	0.085	6.70
1987	1.216	1.267	0.051	4.03
1988	1.267	1.267	0.000	0.00
1989	1.085	1.267	0.182	14.36
1990	1.010	1.267	0.257	20.28[1]
1991	1.010	1.085	0.075	6.91
1992	0.980	1.010	0.030	2.97
1993	0.933	1.010	0.077	7.62
1994	0.990	0.990	0.000	0.00
1995	0.982	1.000	0.018	1.80
1996	1.000	1.000	0.000	0.00
1997	0.980	1.000	0.020	2.00[1]
1998	0.970	1.000	0.030	3.00[1]
1999	0.960	-	-	-
Mean NEY				4.33
Mean EY				7.33
Net El Nino Effect				-3.00

Note: [1] year with major El Nino episode.

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 estimation showed that the dummy variable for the El Nino years was significant at the 10% level of probability (Appendix 1). This indicated that the El Nino in some way or other did affect rubber yields.

Table 5.8 Estimated net loss of the 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

5.4 Rice

5.4.1 Background of the rice industry

The rice subsector has always been considered strategic and has been accorded special treatment by the government. Rice is a socio-economic and political crop that affects both the welfare of producers and consumers alike. Since rice is a staple, Malaysia feels that an acceptable level of self-sufficiency needs to be maintained. In addition, the sector consists mainly of small farmers, many of whom are poor. Rice cultivation is home to about 116,000 households who depend on rice cultivation as a major source of income. This represents about 3% of the total households in the country. Additionally, there are another 200,000 households that are engaged in rice farming as a secondary source of income. In short, it is a highly socially sensitive sector where public policies need to be carefully balanced to ensure that the urban poor consumers are not burdened with high rice prices and the rural poor rice producers are able to obtain a decent income from rice farming. It is, thus, a sector with heavy government intervention. Its strategic role in society has made rice one of the most important agricultural commodities in the country. Massive public investment in terms of infrastructural development including irrigation facilities and support services are made available to the industry. Despite the support given to rice production by the government, income from rice farming is still relatively low.

Rice planted area increased from 530,120 hectares in 1980 to 692,389 hectares in 1999. This increase in planted area was mainly due to the increase in cropping intensity as a result of better irrigation infrastructure and water management. In Peninsular Malaysia, rice production is concentrated in the eight designated main rice-producing areas, also known as the main granaries. These areas are actually major irrigation schemes, which together account for about 80% of total cultivated area for rice. Malaysia's rice production is just over 2 million tons and the country still imports 20 – 25% of its requirement. Despite an increasing trend in domestic production, imports have also increased (Table 5.9). Total imports in 1999 totalled 611,900 tons.

Considering the sensitivity and the strategic nature of the rice industry, it is important that external shocks and disturbances resulting in negative performance of the industry be minimized. In this perspective, the El Nino phenomena and their effects on the rice industry need to be appropriately assessed.

Table 5.9 Rice production and imports, Malaysia, 1980 - 1999.

Year	Rice Production	Rice Imports
1980	1,760,772	202,800
1981	1,748,768	148,817
1982	1,639,785	244,705
1983	1,564,419	358,256
1984	1,397,554	436,519
1985	1,660,857	428,413
1986	1,698,215	191,180
1987	1,605,165	196,507
1988	1,647,552	302,007
1989	1,717,875	367,732
1990	1,884,984	330,336
1991	1,926,354	399,889
1992	2,012,732	443,923
1993	2,104,447	389,196
1994	2,138,788	335,422
1995	2,127,271	427,570
1996	2,228,489	577,463
1997	2,119,615	646,500
1998	1,944,240	657,870
1999	2,036,641	611,900

Source: Ministry of Agriculture, various issues and Statistical Department.

5.4.2 Effects of El Nino on rice

There is no distinct usual relationship between rice yields and temperature (Figure 5.5). An increase in temperature can lead to an increase in yield (1984–1986; 1993–1997). Increasing temperatures can also lead to decreasing yields (1997-1998). Available literature as described in the previous chapter shows that temperature has an inverse relationship with yield i.e. a lower temperature should lead to a corresponding increase in yield levels. However, since temperature in rice growing areas in Malaysia is already in the optimum temperature range, slight fluctuations in temperature would most likely not significantly affect yields. Temperature fluctuations resulting from the El Nino were also not severe, pointing to the fact that even a distinct relationship between the El Nino and temperature may not even exist.

A more reliable El Nino indicator is rainfall. It is evident that the years with major El Nino episodes received less rainfall as indicated by points r_E in Figure 5.6. On average, there seemed to be a pattern of positive associationship between rainfall and rice yields, where higher rainfall tends to improve average yields.

Figure 5.5 Rice yield and average daily temperature pattern, Malaysia, 1980 - 1999.

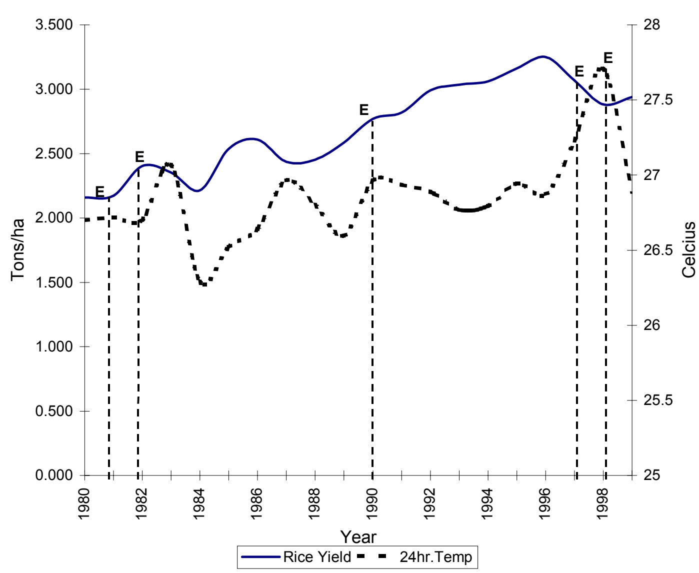
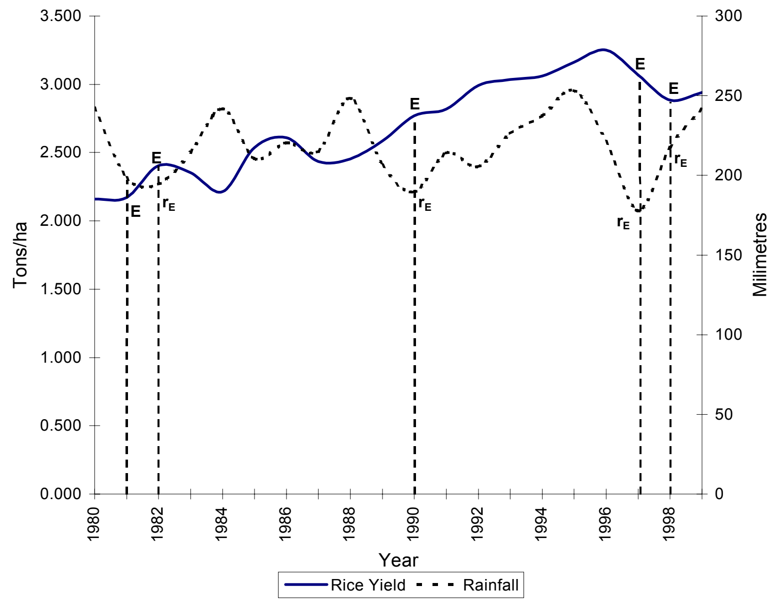
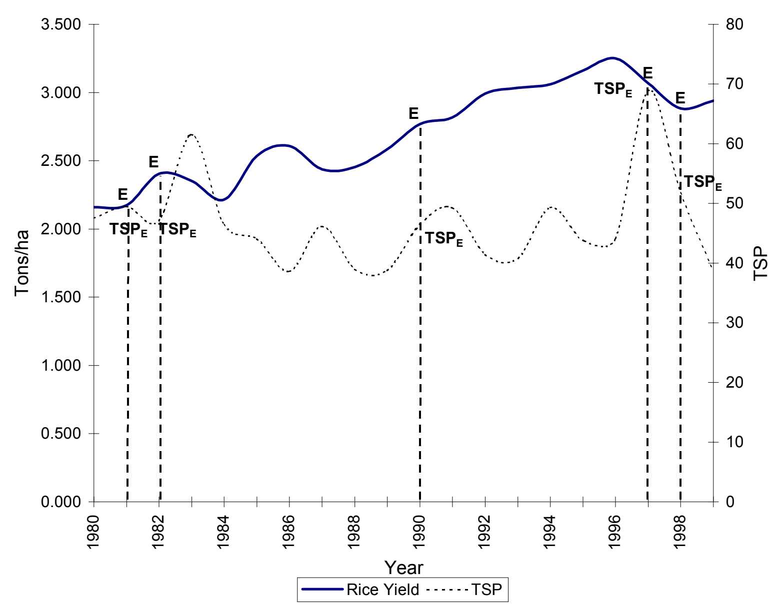


Figure 5.6 Rice yields and rainfall pattern, Malaysia, 1980 - 1999.



In Figure 5.7, rice yields and TSP patterns are shown. El Nino years tend to have higher TSP resulting in hazy conditions. Although no distinct relationship can be concluded from the graph, on a few observed points, rice yields tend to decrease with increase a TSP.

Figure 5.7 Rice yields and TSP pattern, Malaysia, 1980 - 1999.



An analysis similar to that applied to oil palm and rubber was also conducted on rice yields. The results are tabulated in Table 5.10. Yield loss due to weather variability was 0 to 15%. 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 were done 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 show that at the national level, the net effect of the El Nino was only – 1.15%. The net loss computed for the rice industry was estimated to be about RM 218 million (Table 5.11).

A regression analysis similar to that applied to palm oil and rubber was also undertaken for rice. The results show 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% probability level (Appendix 1).

Table 5.10 Estimated loss of rice yield due to weather variability, Malaysia, 1980 - 1999.

Year	Yield	Five Year Moving Maximum Yield	Difference	% Loss
1980	2.159	-	-	-
1981	2.173	2.404	0.231	9.61[1]
1982	2.404	2.404	0.000	0.00[1]
1983	2.352	2.536	0.184	7.26
1984	2.215	2.609	0.394	15.10
1985	2.536	2.609	0.073	2.80
1986	2.609	2.609	0.000	0.00
1987	2.436	2.609	0.173	6.63
1988	2.453	2.769	0.316	11.41
1989	2.586	2.818	0.232	8.23
1990	2.769	2.992	0.223	7.45[1]
1991	2.818	3.035	0.217	7.15
1992	2.992	3.061	0.069	2.25
1993	3.035	3.162	0.127	4.02
1994	3.061	3.251	0.190	5.84
1995	3.162	3.251	0.089	2.74
1996	3.251	3.251	0.000	0.00
1997	3.068	3.251	0.183	5.63[1]
1998	2.883	3.251	0.368	11.31[1]
1999	2.941	-	-	-
Mean NEY				5.65
Mean EY				6.80
Net El Nino Effect				-1.15

[1] Year with major El Nino episode.

Table 5.11 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

5.5 Fruits

5.5.1 Background of the fruit industry

Fruit growing is smallholder-based agriculture with involvement of about 270,000 farmers (Ministry of Agriculture 1999). The major types of fruits cultivated are durian, watermelon, pineapple, banana, rambutan, starfruit and papaya. It is a relatively small industry compared to oil palm, rubber and rice. Its contribution to agricultural GDP is less than 3%. Despite its small nature, fruit cultivation is moving towards increased commercialization. More small and medium sized fruit farms are now being developed as compared to the previous backyard structure of the industry. Increasing factor costs such as land and labor have forced agricultural enterprises into higher value crops that are more profitable, such as horticultural crops including fruits. This situation, coupled with the government's encouragement and fiscal support has led to a rapid expansion of the industry.

The area under fruits has increased by over 240% over the last two decades (Table 5.12). In 1999, total area under fruits reached more than 260,000 hectares, with production of over 1.4 million tons, Exports too have swelled to RM 388 million from just RM 59 million in 1986, a growth of more than 650% over just 13 years.

Table 5.12 Area, production and exports of fruits, 1980 – 1999, Malaysia.

Year	Area (ha)	Production (tons)	Exports (RM)
1980	76,453	-	-
1981	71,394	-	-
1982	75,570	-	-
1983	77,170	-	-
1984	116,653	806,107	-
1985	118,323	839,888	-
1986	112,656	855,984	-
1987	138,249	988,306	58,874,717
1988	145,095	1,051,447	76,510,457
1989	157,711	1,022,039	121,248,952
1990	172,026	1,136,016	142,404,088
1991	187,476	1,366,007	208,448,045
1992	193,626	1,500,691	217,120,349
1993	230,951	1,752,395	273,392,958
1994	263,645	1,852,100	265,010,806
1995	257,654	1,348,134	225,951,005
1996	262,113	1,226,742	255,000,707
1997	260,882	1,211,397	258,761,502
1998	257,605	1,257,503	297,937,681
1999	261,789	1,410,916	387,968,974

Source: Ministry of Agriculture, various issues and Statistical Department.

5.5.2 Effects of El Nino on the fruit industry

Measuring the actual impacts of the 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 area and production of each fruit type in each year is not in constant proportion and therefore the simple mean might not a good indicator of the actual mean, which should be the weighted average. However, data on individual fruit crops are not available to enable a computation of the weighted means. Second, there are no records of mature and immature fruit areas. As such the mean yield computed is not reflective of the productive areas under fruits. This bias in calculating the mean yields for the respective years might lead to bias in estimating yield loss due to weather variability.

Hence, the following analysis of yield loss due to weather variability on fruits is based on two major assumptions:

- the expansion in the respective specific fruit area from year to year is proportionate to each other, and
- the proportion of immature areas over the years is constant, thus erasing the bias in comparison of yields between years.

Table 5.13 shows the analysis of yield loss due to weather variability of fruits for the 1984 – 1999 period. Yield loss ranges from 0 to more than 33%. It is interesting to note that the highest yield loss of 33% took place in a non-El Nino year. The effects of the El Nino on fruits are assumed to be effective in the current year and the subsequent year to reflect the the lag interval effect of this environmental variable on perennial crops.

Based on the analysis, the mean yield loss for the NEY was 10.25% while for the EY, the computed mean was 10.84%. Therefore, the net affect of the El Nino is only -0.59%. Therefore, the 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 the El Nino in affecting productivity in fruits.

Table 5.13 Estimation of yield loss of fruits due to weather variability.

Year	Yield (tons/ha)	Five Year Moving Maximum	Difference	% Loss
1984	6.90	-	-	-
1985	7.09	-	-	-
1986	7.60	7.60	0.00	0.00
1987	7.15	7.60	0.45	5.92
1988	7.24	7.60	0.36	4.74
1989	6.48	7.28	0.80	10.99
1990	6.60	7.75	1.15	14.84[1]
1991	7.28	7.75	0.47	6.46[1]
1992	7.75	7.75	0.00	0.00
1993	7.58	7.75	0.17	2.19
1994	7.02	7.75	0.73	9.42
1995	5.23	7.58	2.35	31.00
1996	4.68	7.02	2.34	33.33
1997	4.64	5.28	0.64	12.12[1]
1998	4.88	5.28	0.40	7.58[1]
1999	5.28	-	-	-
Mean non-El Nino affected years				10.25
Mean El Nino affected years				10.84
Net El Nino effect				0.59

Note: [1] El Nino affected years are assumed to be the El Nino year and one year after the El Nino episode, i.e. the lag effect.

5.6 Vegetables

5.6.1 Background of the vegetable industry

Vegetable cultivation is also smallholder-based. Average farm size ranged from only 0.2 to 1.2 hectares (Department of Agriculture 1997). There are more than 50 types of vegetables grown in Malaysia consisting of the leafy, fruit and root vegetables. The most widely planted fruit vegetables are long beans, chilly, cucumber, lady's finger, french beans, luffa and brinjal, while the popular leafy ones are choysum, spinach, brassicas and cabbages. Production takes place in both the lowlands and highland. Highland vegetables comprise tomato, ginger and cabbages.

Vegetable area has somewhat stabilized at between 30,000 – 34,000 hectares for the past five years (Table 5.14). Production in 1999 was estimated at about 309,000 tons. Malaysia also exports vegetables, mostly to neighboring Singapore and Brunei. Exports have been increasing and had reached RM 186 million in 2000. Imports were much higher at more than RM 792 million, consisting mainly of onions, shallots, garlic, potatoes and temperate vegetables.

Table 5.14 Area, exports and imports of vegetables, Malaysia, 1980 – 2000.

Year	Area (ha)	Production (tons)	Exports (RM)	Imports (RM)
1980	16,954	-	-	-
1981	13,817	-	-	-
1982	7,650	145,343	-	-
1983	7,595	149,668	-	-
1984	11,565	128,454	-	-
1985	10,506	92,745	-	-
1986	11,785	94,892	-	-
1987	12,086	110,933	-	-
1988	16,592	137,514	49,366,000	190,717,000
1989	26,597	152,898	70,322,000	197,422,000
1990	26,873	440,997	76,192,278	305,786,614
1991	24,649	435,526	43,049,427	346,261,044
1992	28,868	420,244	59,716,629	352,102,395
1993	29,736	434,842	108,751,911	412,205,877
1994	35,293	429,033	94,776,287	443,004,270
1995	33,759	290,569	100,925,063	560,422,128
1996	32,017	270,745	105,461,047	655,002,614
1997	30,199	253,461	120,034,854	731,829,290
1998	32,601	301,791	137,535,897	855,078,949
1999	32,127	309,148	176,833,771	917,118,524
2000	-	-	186,052,497	792,403,574

5.6.2 Effects of El Nino on vegetables

Estimating the effects of the El Nino on vegetable yields also faced similar constraints as in the case for fruits. The results of the analysis are given in Table 5.15. 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 leads to wide variations in the estimated yield loss due to weather variability, which ranged from 0 to 67.46%. The mean yield loss estimated for the EY and the NEY years showed that yield loss during EY was much lower than the NEY. This indicates that it is unlikely that the El Nino had any major influence on vegetable yields. This finding is quite acceptable considering that almost all vegetable growers irrigate their crops. As such, any deficiencies in water requirement due to prolonged dry periods and low rainfall can be easily corrected. It is more likely that excessive rains causing floods would do more damage to vegetable cultivation compared to insufficient rain.

Table 5.15 Estimated yield loss for vegetables due to weather variability, 1982 – 1999.

Year	Yield (tons/ha)	Five Year Moving Maximum	Difference	% Loss
1982	19.00	-	-	-
1983	19.71	-	-	-
1984	11.11	19.71	8.60	43.63
1985	8.83	19.71	10.88	55.20
1986	8.05	11.11	3.06	27.54
1987	9.18	9.18	0.00	0.00
1988	8.29	16.41	8.12	49.48
1989	5.75	17.67	11.92	67.46
1990	16.41	17.67	1.26	7.13
1991	17.67	17.67	0.00	0.00[1]
1992	14.58	17.67	3.09	17.48
1993	14.62	17.67	3.05	18.30
1994	12.16	14.62	2.46	16.83
1995	8.61	14.62	6.01	41.08
1996	8.46	12.16	3.70	30.43[1]
1997	8.39	9.62	1.53	15.90[1]
1998	9.26	9.62	0.00	0.00
1999	9.62	-	-	-
Mean for EY				15.44
Mean for NEY				28.68
Difference				13.24

Note: [1] Year with major El Nino episode.

5.7 Sugarcane

5.7.1 Background of the sugarcane industry

Sugarcane cultivation is not extensive in Malaysia. It is mainly concentrated in the northern states of Peninsular Malaysia. Two major private producers are the main players, accounting for almost 90% of the total area under sugarcane. Area under the crop has been stagnant at about 21,000 – 23,500 hectares for the last 15 years due to limited suitable areas and competition for land with other crops and other economic activities.

5.7.2 Effects of El Nino on sugarcane

National level data on sugarcane are limited to planted area. As such no analysis can be made on yield performance over the years. Consequently, the analysis on the effects of the El Nino for sugarcane is confined to its affect on planted area.

The area under sugarcane did not show any response to the El Nino years (Table 5.16). Areas in the prior and subsequent few years after the El Nino episodes did not show significant positive or negative response that can be attributed to the El Nino. Further research on productivity at the micro-level needs to be conducted to generate more conclusive evidence.

Table 5.16 Area under sugarcane, Malaysia, 1980 –1999.

Year	Area
1980	12,705
1981	13,011[1]
1982	20,250[1]
1983	17,029
1984	20,975
1985	21,643
1986	22,052
1987	20,406
1988	20,975
1989	20,375
1990	21,574[1]
1991	22,542
1992	23,504
1993	22,384
1994	22,117
1995	22,050
1996	22,320
1997	21,897[1]
1998	22,043[1]
1999	21,411

Note: [1] Year with major El Nino episode.

5.8 Fisheries

5.8.1 Background of the fisheries industry

Fisheries is an important component of agricultural value-added in Malaysia. It is the second largest contributor to agricultural GDP after oil palm. The sector comprises three main components namely the inshore and deep-sea fisheries and aquaculture. Inshore fisheries is the main contributor to fish supply accounting for over 75% of total supply, while the remainder is almost evenly divided between deep-sea and aquaculture. Lack of willing domestic crewmen and skilled manpower are the main factors constraining a faster expansion in deep-sea fish captures. Under such a supply structure, Malaysian fisheries are relatively small compared to its ASEAN neighbors such as Thailand and Philippines, where deep-sea fishing and 'mother-boats' form the main source of fish supply. Currently, it is estimated that there are about 80,000 fishermen in the country, the majority of them in the inshore fishing sub-sector.

5.8.2 Effects of El Nino on fish capture

There is no evidence as yet that can link fish availability in the seas to the El Nino. However, in the Malaysian condition El Nino can indirectly influence fish capture. Long dry spells of the El Nino resulted in hazy conditions and a high level of pollution in Malaysia, Indonesia and Singapore. Industry sources cited the hazy conditions as a constraint to fishing due to unhealthy weather conditions and poor visibility at sea. A graph plotting fish landing patterns and TSP levels was drawn to observe if any relationship between the two variables existed (Figure 5.8). From the figure, it is clear that annual fish landings are independent from any influence of TSP.

Figure 5.8 Marine landings and TSP pattern, Malaysia, 1980 – 1999.

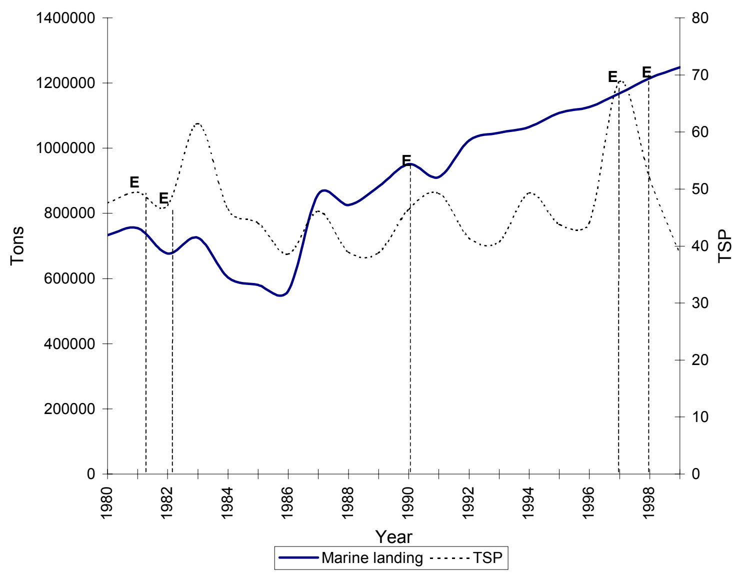


Table 5.17 Estimation of marine landing loss from El Nino.

Year	Marine Landings ('000 tons)	Five Year Moving Maximum	Difference	% Loss
1980	733.7	-	-	-
1981	755.4	-	-	-
1982	676.5	755.4	78.9	10.44[1]
1983	725.0	755.4	30.4	4.02
1984	603.3	725.0	121.7	16.78
1985	580.8	859.0	278.2	32.39
1986	561.6	859.0	297.4	34.62
1987	859.0	882.5	23.5	2.66
1988	825.6	951.3	125.7	13.21
1989	882.5	951.3	68.8	7.23
1990	951.3	1,023.5	72.2	7.05[1]
1991	911.9	1,047.4	135.5	12.94
1992	1,023.5	1,065.6	42.1	3.95
1993	1,047.4	1,108.4	6.1	5.50
1994	1,065.6	1,126.7	61.1	5.42
1995	1,108.4	1,169.0	60.6	5.18
1996	1,126.7	1,215.2	88.5	7.28
1997	1,169.0	1,215.2	46.2	3.80[1]
1998	1,215.2	1,248.4	33.2	2.66[1]
1999	1,248.4	-	-	-
Mean NEY Loss				10.86
Mean EY Loss				5.99
Net El Nino effect				4.87

Note: [1] Year with major El Nino episode.

To further strengthen the above observation, an analysis similar to that applied to the crop commodities was done for marine landings (Table 5.17). Results show that mean marine landing loss for NEY was in fact higher than that of the EY. Therefore, it can be concluded that there is no real link between fish landings, the level of TSP and the El Nino episodes. It may be that the duration of the haze is too short to have any significant effect on annual marine landings.

5.8.3 Effects of El Nino on aquaculture production

Technical studies have indicated that haze from El Nino tends to negatively effect yields of aquaculture farms. This is due to the unhealthy conditions caused by high atmospheric pollution that affects survival rates and weight gain of prawns, fishes and other aquacultural species. Tables 5.18 and 5.19 show the yields of aquaculture farms in 'pool-type' and 'cage-type' production systems. In the pool-type system, yields were rather erratic and vary widely between the years. Yields varied between 0.79 tons and 3.58 tons per hectare, showing a variation of over 3.5 times. Unexpectedly, it is interesting to note that out of three highest yields registered in the time-series, two of them were registered during the most severe El Nino years of 1997 and 1998. From these observations alone, it can be concluded that the El Nino has no significant effect on the annual productivity of the pool-type aquaculture farms. Similar observations could be made for the cage-type production system. Yields were fairly consistent through the years except for one or two outliers.

Table 5.18 Aquaculture yields in pool-type production system.

Year	Area (ha)	Production (tons)	Yield (tons/ha)
1980	2,925.38	8,210.84	2.81
1981	5,617.13	9,230.21	1.64
1982	5,123.32	14,424.68	2.82
1983	5,413.24	12,353.94	2.28
1984	4,990.62	3,973.80	0.79
1985	4,694.39	6,540.46	1.39
1986	4,421.98	5,012.24	1.13
1987	3,828.05	3,532.21	0.92
1988	4,397.56	9,091.18	2.07
1989	5,483.37	10,185.64	1.86
1990	6,441.19	12,218.00	1.90
1991	7,136.45	13,893.98	1.95
1992	8,360.22	18,732.97	2.24
1993	7,631.79	18,875.65	2.47
1994	10,086.29	22,791.40	2.26
1995	9,145.68	23,261.03	2.54
1996	9,184.63	27,944.43	3.04
1997	12,873.57	37,632.90	2.92
1998	11,656.30	41,683.28	3.58

Source: Department of Fisheries, Malaysia. Unit of production.

Table 5.19 Aquaculture yields of cage-type production system.

Year	Volume (m^2)	Production (t)	Yield (t/m^2)
1982	49,177.78	440.69	0.00896
1983	43,959.58	555.98	0.01265
1984	51,572.41	107.07	0.00208
1985	82,339.52	408.12	0.00496
1986	90,359.96	967.36	0.01071
1987	117,833.83	1,268.96	0.01077
1988	165,328.49	1,631.76	0.00987
1989	220,937.13	2,036.40	0.00922
1990	264,384.12	2,570.77	0.00972
1991	326,390.52	2,704.45	0.00829
1992	426,845.78	3,852.86	0.00901
1993	716,953.27	6,979.78	0.00973
1994	736,235.16	7,041.87	0.00956
1995	794,785.42	7,295.66	0.00921
1996	944,305.08	6,929.44	0.00734
1997	821,578.68	7,502.72	0.00913
1998	837,775.37	8,062.94	0.00962

Source: Department of Fisheries, Malaysia. Unit of production.

To investigate in more detail the effects of the El Nino on aquaculture, the yield-loss analysis based on the five-year maximum was conducted. The results confirmed the above observation that a relationship between El Nino and aquaculture yield cannot be established (Table 5.20 and 5.21). It is likely that other more important factors are at work influencing the annual yields of aquaculture farms.

Table 5.20 Estimated yield loss from aquaculture pool system due to weather variabilty.

Year	Yield (tons/ha)	Five Year Moving Maximum	% Loss
1980	2.81	2.82	0.35
1981	1.64	2.82	41.84[1]
1982	2.82	2.82	0.00[1]
1983	2.28	2.82	19.15
1984	0.79	2.82	71.99
1985	1.39	2.28	39.04
1986	1.13	2.07	45.41
1987	0.92	2.07	55.56
1988	2.07	2.07	0.00
1989	1.86	2.07	10.14
1990	1.90	2.24	15.17[1]
1991	1.95	2.47	21.05
1992	2.24	2.47	9.31
1993	2.47	2.54	2.76
1994	2.26	3.05	25.90
1995	2.54	3.05	16.72
1996	3.05	3.58	14.80
1997	2.92	3.58	18.44[1]
1998	3.58	3.58	0.00[1]
Mean EY			15.09
Mean NEY			23.94
Net El Nino effect			8.85

Source: Department of Fisheries, Malaysia. Unit of production.

Table 5.21 Estimated yield loss from aquaculture cage system due to weather variabilty.

Year	Yield (t/ha)	Five Year Moving Maximum	% Loss
1982	8.96	12.65	41.18[1]
1983	12.65	12.65	0.00
1984	2.08	12.65	83.56
1985	4.96	10.77	53.95
1986	10.71	10.77	0.56
1987	10.77	10.77	0.00
1988	9.87	10.77	8.36
1989	9.22	10.77	14.39
1990	9.22	9.87	1.52[1]
1991	8.29	9.73	14.80
1992	9.01	9.86	8.62
1993	9.73	9.86	1.32
1994	9.86	9.86	0.00
1995	9.21	9.86	6.59
1996	7.34	9.86	25.56
1997	9.13	9.86	7.40[1]
1998	9.62	9.86	2.43[1]
Mean EY			13.13
Mean NEY			16.75
Net El Nino effect			3.62

Source: Department of Fisheries, Malaysia. Unit of production.

5.9 Livestock

5.9.1 Background of the livestock industry

The livestock industry is the third most important contributor to agricultural value added after oil palm and fisheries. Output was estimated at about RM 5 billion, of which poultry and pork accounted for about 95% of the total. Other important subsectors are beef, mutton and milk. Table 5.22 shows the production of the various livestock subsectors from 1980 to 1999. Production is mainly geared to fulfilling domestic demand, although some poultry and pork are exported to Singapore. The majority of the producers in the various subsectors consist of smallholders except for poultry. Poultry production is mainly undertaken by the big integrated feed-farm companies, which collectively account for about 75% of total production. Milk, beef and mutton are relatively small industries.

Table 5.22 Production of selected livestock subsectors, Malaysia, 1980 – 1999.

Year	Poultry	Beef	Mutton	Pork	Poultry Eggs	Milk
		('000 tons)			(million)	(mil. liter)
1980	114.5	13.0	0.8	122.6	2,311	8.2
1981	130.1	12.1	0.6	124.7	2,270	14.9
1982	142.0	13.7	0.6	126.7	2,373	16.7
1983	160.0	13.3	0.6	128.3	2,686	18.9
1984	180.0	13.1	0.6	137.3	2,857	20.2
1985	221.4	12.4	0.6	147.5	3,076	21.8
1986	285.5	14.0	0.6	172.6	3,709	26.1
1987	267.6	14.1	0.5	189.6	3,818	27.4
1988	341.9	15.3	0.5	198.7	4,251	27.8
1989	393.9	13.5	0.6	183.4	4,309	27.1
1990	388.6	13.7	0.7	226.6	5,555	28.9
1991	436.0	14.3	0.7	233.3	5,612	29.0
1992	544.1	14.8	0.7	250.9	6,320	31.2
1993	610.7	15.3	0.6	262.8	6,288	33.1
1994	649.8	15.2	0.7	284.8	6,578	35.5
1995	687.4	16.9	0.7	283.4	6,817	36.8
1996	645.3	15.9	0.6	276.6	6,959	36.2
1997	712.9	16.0	0.6	282.3	7,038	33.8
1998	673.7	16.7	0.7	262.4	7,098	31.7
1998	690.0	18.3	0.9	158.8	6,709	28.8

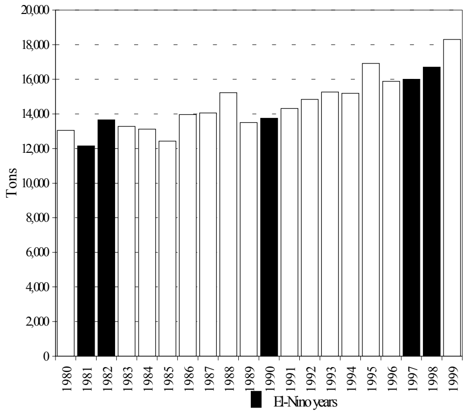
Source: Ministry of Agriculture (1999).

5.9.2 Effects of El Nino on the livestock industry

Technically, dry periods would not have any direct effects on livestock productivity. Daily water needs of the livestock could be easily supplemented by producers. However, there are suspicions that dry weather conditions in Malaysia that led to the formation of haze and a polluted atmosphere could subsequently cause health problems in livestock. The polluted atmosphere may cause respiratory problems that can result in higher mortality rates, especially among starter poultry and young livestock species. Production could then be affected.

Figures 5.9 – 5.14 show the patterns of livestock production in Malaysia for the 1980-1999 period. The grid bar chart represents production in the years with major El Nino episodes, i.e. in 1981, 1982, 1990, 1997 and 1998. For all the livestock products, it appears that production was not affected by the El Nino. In fact for some products, peak production took place during the El Nino years (poultry eggs for 1998 and poultry meat for 1997). The patterns of production did not show any relationship with the occurrence of the El Nino. It can be safely concluded that at the macro level, the effect of the El Nino on livestock production is insignificant.

Figure 5.9 Beef production in Malaysia, 1980-1999.



5.10 Summary of impacts

The analyses carried out provide strong evidence of the negative effects of the El Nino on Malaysian agriculture. Total losses to agriculture as a result of poorer crop performances of oil palm, rubber and rice due to the El Nino were estimated to be more than RM 3.4 billion for the 1980 to 1999 period. Hardest hit was the palm oil industry with estimated losses of RM 2,839 million, followed by rubber with about RM 357 million and rice with almost RM 218 million. These estimated losses do not yet to take into account the secondary spin-off losses resulting from loss of production value of other downstream and derivative products of palm oil, rubber and rice. Results from the regression analyses also show that the El Nino episodes significantly affect yield. Results also showed that rainfall and total suspended particulate are important variables that affect yields of oil palm and rice. The country also incurred loss in terms of foreign exchange as a result of the loss from potential export earnings of palm oil and the need to import more rice to fulfill the country's demand. Based on the ratio that about 75% of Malaysia's production of palm oil in 1998 was exported, the total loss in exports in the EY was RM 2129 million. For rubber foreign exchange losses were estimated at RM 179 million.

For the other sub-sectors there was no evidence that could link productivity with the El Nino. The findings on losses for livestock products were consistent with the findings from Nordin et al. (1998) who observed no significant productivity losses for livestock products resulting from the El Nino. In capture fisheries, however, Shahwahid and Jamal (1998) reported an economic loss of about RM 40 million in 1997 as a result of the haze. The study, however, only compared month to month marine landing data for the haze period in 1997 and the corresponding period in 1996 to compute the loss. The findings from this study show no evidence to support the study by Shahwahid and Jamal (1998). In aquaculture, Fatimah Md. Yusoff (1998) also reported losses in productivity of prawns due to lower weight gain and lower survival rates. In contrast, macro aggregated data used in this study found no effects on aquaculture productivity as a whole that can be attributed to the El Nino. The aggregation of data in this study might have diluted the effects of the El Nino and the haze on shrimp production.

Due to the wide variations in weather conditions across the country, the effects and impacts of the El Nino can also be varied. Therefore, further in-depth research needs to be carried out at the micro-level in different locations and on different agricultural enterprises to evaluate the actual effects and impacts of the El Nino.

6. Institutional Preparedness

Institutional preparedness represents mitigating measures established to reduce the adverse impact of El Nino induced weather change. 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 the annual crops, where crop management in terms of crop care, crop choice and crop scheduling are more flexible compared to that of perennial crops. This chapter is devoted to identifying major mitigating measures undertaken either by government institutions or the farmers. All of these measures, as indicated below, were undertaken to reduce the impact of either the drought or the haze, or both.

6.1 Climate monitoring and forecasting

The importance of monitoring and forecasting as a tool in reducing the impact of climate variability is well accepted. The United Nations (2000) declared that thousands of human casualties and billions of dollars in economic damage will continue to befall the world's developing countries every two to seven years until major investments are made to improve the existing forecasting and preparedness for El Nino. The El Nino event of 1997/98, and the associated forecasting and early warning system established, has shown to some extent the capability of the system in providing some lead time for the affected nations to prepare for the consequences. Hence, the event was well forecasted by the experts, and some degree of mitigating measures were instituted.

In Malaysia, the main agency responsible for the monitoring and forecasting of climate variability is the Malaysian Meteorological Services (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. The monitoring of air quality is now privatized to increase its efficiency and coverage, with a network of 29 air quality-monitoring stations. This will be increased to 50 in the future.

Specifically in relation to El Nino incidence, MMS had 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. Other than the World Meteorological Organization (WMO), the monitoring of the ENSO situation could be easily accessible through various Internet sites. The International Research Institute for Climate Prediction, the Climate Diagnostic Center and American Geophysical Unions are some examples of institutions that provide these services. Additionally, NOAA is operating a network of buoys to measure temperature, currents and winds near the Equator. These data have been used to predict short-term climate variation for specific regions around the world. This information, to some extent has been utilized by this country. At the same time, MMS also performs analyses on historical and operational meteorological data for its observational network. With this information, the public was advised about the impacts of the impending El Nino with respect to its weather change and some indications on possible impacts on the various economic sectors.

The monitoring on air quality in the country, particularly haze, was done by MMS using two measurements, the Air Pollution Index (API) and the Visibility Index. In this regard, the visibility is measured as the furthest distance from which a person can see a landscape. The quality of air, on the other hand is monitored by using a number of known pollutants. Under the National Air Quality Monitoring Program, MMS monitors atmospheric conditions related to weather as well as some parameters relating to the ambient air quality. One parameter measured is Total Suspended Particulate (TSP) concentration in air, which is directly related to haze intensity. The other pollutants measured are carbon monoxide, sulphur dioxide, nitrogen dioxide and ozone. The Air Pollutant Index (API) is then calculated for each type of pollutant and the highest API of the five pollutants measured represents the air quality of the ambient air for a specified period of time. Currently, API is the standard system of measuring air pollution levels in this country, and it serves as an indicator of air quality in terms of impact on human health. Based on this index, air quality is characterized between good (API value 0-50), moderate (50-100), unhealthy (101-200), very unhealthy (201-300) and hazardous (301-500). These are used as triggers for the type of actions to be taken by government and the population.

This information enhances predictive capability to forecast the El Nino event, and ability to provide some lead-time to prepare for the impending El Nino related impacts. What is lacking probably is the ability to relate climatic variability and fluctuation, including the ENSO parameter, and its impact on crop yield. This seems to be the weak link; hence the level of predictability on crop production with changes in climate across region has not been well established. This gap will make it impossible to develop a predictive tool, be it some form of simulation model or expert system, capable of advising farmers on what crop to plant, where and when with the impending changes in climate. Such prediction, and its derived benefit in knowing what a cropping season is going to be, would allow farmers and governments to take the necessary preventive measures in terms of crop management, marketing and pricing. Until and unless this is developed, the benefit of forecasting will not be optimized to improve the decision-making processes.

In view of the limited national capacity in this area of expertise, the country has established several regional and global partnership initiatives in the areas of research, training and information sharing. This includes the country's involvement with the International Biosphere Program (IBBP), World Climate Research Program (WCRP) and International Human Dimension of Global Environmental Change Program (IHDP).

6.2 Water resource management

Water resource management and utilization presents a major challenge to the nation. This is especially so within the current environment of rapid economic and social growth and development, at the same time as water resources are being depleted due to the encroachment of economic activities in some water catchment areas. Current land use activities have to some extent resulted in the degradation of existing catchment areas and an increase in water turbidity due to sediment load from both industrial and agricultural effluent. Hence, water resource management must take into account the increased possibility of reduced quantity and quality of the resource in the future. The more severe climate variability such as the El Nino, which influenced the annual level of precipitation in the country, compounded the problem further. On the other hand, the future will see an increased demand for water for all purposes, be it for household and industrial use, as well as for agricultural purposes.

The last El Nino episode showed that the country as a whole experienced water supply strains, albeit at a different degree of seriousness. This was due to the prolonged drought, at the same time when the demand for water supply to support the requirement for household, industrial and agricultural purposes had been on the rise. Therefore, any mitigating measures to address the problems associated with water shortage and deficiency must take into account how well the existing water resources are managed.

At the aggregate level, there is an abundant supply of rainwater in relation to demand, with the average rainfall estimated to be in the region of 990 billion metric cubic meters (Sivalingam 1994). Of this, only about 1.3% was used to service the domestic, industrial and irrigation demands for water. The rest was 'lost' in the form of surface runoff, groundwater recharge and returned to the atmosphere through evapotranspiration. The rapid runoff and the uneven distribution of rainfall during the year necessitates the building of storage dams and reservoirs. In spite of that, under the situation of prolonged drought brought about by El Nino, as was seen in the 1997/98 episodes, the drying up of these dams and reservoirs affected water supply for both household and agricultural purposes.

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 deficit have been on-going. Several measures have been taken within the irrigation schemes to continue to upgrade the water use efficiency at all irrigation schemes and to avoid unnecessary wastage.

In the last El Nino episode, the associated drought (and haze) did not have a very significant impact on rice production in all granaries. It seems that the existing infrastructures in place were able to mitigate some of the possible impacts. In most granaries, there was still an adequate supply of irrigation water, especially during the paddy planting and growing period. The continued monitoring of water resources, the application of recycled water for water conservation, an efficient water distribution mechanism and the appropriate water schedule (taking into consideration the possible impact of El Nino) managed to minimize the onslaught of El Nino induced climate variability, particularly the drought. The most critical periods of rice production with regard to water requirement are during the planting and development periods, both of which were scheduled outside the peak of the El Nino period. Since the peak water shortage occurred during the panicle initiation and ripening stage, water availability then was not very critical. That scheduling had helped in mitigating the possible serious impacts of drought on paddy production. Hence, whilst the area of crop failures due to drought in some granaries was high as compared to non-El Nino years, the loss constituted less than 1% of the total paddy planted area. For example, for the year 1977 in the state of Kedah where the MADA Irrigation Scheme is situated, a total of 2,241 ha of paddy fields were destroyed resulting in zero harvest. Out of this, 1,547 ha were due to drought. This however, represents only 0.7% of the total paddy area in the state.

A simple, indigenous technology for water management has been practiced in the sugarcane plantations. Since all the sugar plantations are located in the 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 up small creeks in this hilly and undulating topography. The 'storage' water is sufficient to irrigate the field using mobile sprinkler systems. The system was found to be very reliable, it is cheap and easy to maintain. When the need arises, more 'lakes' could always be constructed.

6.3 Research and development

Research and development activities, as means to address issues related to changes in climatic parameters, have been carried out continuously in this country. Malaysian Agricultural Research and Development Institute (MARDI), and other agricultural R&D institutions and universities have put much effort into producing new varieties and new technologies, as measures to reduce the vulnerability to climate change of agricultural production. Some of these efforts are outlined below:

6.3.1 Development of drought resistant paddy varieties

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 spectrum of rice germplasm, currently totaling about 8,000 accessions, support breeding activities, including for 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 varieties for drought prone areas. The introduction of the Second National Agricultural Policy (NAP) in 1993 and the Third NAP in 1999, however, which called for rice production to be concentrated in the eight granary areas which are equipped with irrigation water supply, reduced the need for the development of such drought resistant varieties and the associated technologies. Nevertheless, the required trait has been kept in the gene bank, and it could be used when the need arises. In the past, several varieties had been identified which were suitable for planting in rainfed and drought prone areas. The adaptability and local verification trials of these varieties in drought prone areas gave yield levels ranging between 2 and 5 tons per hectare (MARDI 1993). Unfortunately, similar measures for other crops are very much lacking.

6.3.2 Water saving technologies

New and improved procedures for on-farm water management have been formulated and developed. To minimize water use at the farm level, improved cultural practices have been introduced which optimize water use efficiency, whilst reducing water loss and wastage. Understanding the 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. These activities were conducted by a number of government agencies, including MARDI, Department of Agriculture, Drainage and Irrigation Department, irrigation scheme authorities as well as local universities and foreign agencies (such as Japan International Research Center for Agricultural Sciences - JIRCAS).

For the perennials, focus was put on improving and promoting newer irrigation techniques, such as drip irrigation, which had been extensively used by farmers in drought prone areas, especially during the planting and establishment period. This is very common in fruit production. Production of annuals other than rice has always been supported with irrigation water, either from rivers or swamps, as well as from underground water.

6.3.3 Haze and crop growth

The 1997/98 haze episode prompted aggressive R&D activities, particularly in assessing the effect of haze on crop performance and productivity. The Ministry of Science, Technology and the Environment aggressively supported several studies on this, which involved many R&D institutions, universities and the private sector. This was a good start, even though the emphasis was more on assessing the impact of haze, and not so much on identifying the measures required to mitigate some of these effects. The most prominent achievement so far would be on the introduction of zero burning during the replanting operation, especially in oil palm plantations. Traditionally, oil palm trees are cut and burned down. This was found to be cheap, practical and effective. Through zero burning, old oil palm trees are felled and cut, piled and left to rot in the field. This reduces the possibility of haze formation since no burning of biomass is taking place, and the rotting palms act as an additional source of organic matter to the growing palm trees. This practice has been extensively used in the country, with full support by the government and plantation sectors.

6.4 New water sources

The previous El Nino episode was considered one of the environmental disasters of the decade as far as its effect on water supply is concerned. This is especially so among the households in Kuala Lumpur. It showed the lack of any contingency plan to deal with the resultant water shortage, especially for household and industrial consumption. Currently, the water demand for the country stands at 2.6 billion cubic meters per annum, and this is expected to soar to 5.8 billion cubic meters by 2020. With the impending and unavoidable El Nino episodes in the future, the challenge to the government with respect to making available the necessary water supply is a great task indeed.

The Malaysia Federal Constitution provides that water is a state matter. Therefore, each individual state in the federation has property nights over the development of water resources within its boundaries. Each state has it own Water Supply Enactment for the protection of water supply catchment areas, and its own institutional arrangement for managing its water resources (Sivalingam 1994). Hence, it is possible for one state to sell its water to another state. However, not all states have been able to buy water when it was needed as was seen in several episodes of water shortage in the past, in spite of the fact that there are states with water surplus.

The previous episode of El Nino, where certain parts of the country, including the Federal capital faced acute water shortages, and at the same time, there was water surplus in adjacent states, prompted the government to take more affirmative action through the National Water Resource Council. The council, headed by the Prime Minister provides a forum for the planning and management of water resources, including the issues of inter-state and inter-basin water transfer (Government of Malaysia 1999). As an immediate solution to address similar water shortages within the Kuala Lumpur vicinity, outsourcing of water supply from the neighboring state of Pahang has been implemented. Similar 'transfer' of water sources from water-surplus areas to water-deficit areas is expected to be enhanced in the future.

Similar emphasis, however, was not placed on identifying new and additional sources for irrigation water. It would seem that at least in the short term, there will not be new sources of irrigation water for agricultural purposes, either from the existing irrigation schemes, or from the new irrigation schemes.

6.5 Policy measures

Environmental and natural resource management of the country is guided by the National Policy on the Environment, which was promulgated to ensure long-term sustainability and improvement in the quality of life. One of the objectives of the policy is to achieve a clean, safe, healthy and productive environment for both the present and future generations (Seventh Malaysia Plan 1996). Action plans have been drawn up to operationalize different aspects of the policy. Special focus has been given to developing a framework for an integrated approach to development, enhancing the effectiveness of the regulatory and institutional framework, recommending suitable mitigation measures, improving environmental education, communication and awareness.

The two federal agencies directly involved with environmental issues, including the haze issue, are the Department of Environment and the Malaysian Meteorological Services, both under the Ministry of Science, Technology and the Environment. As was mentioned earlier, the Malaysian Meteorological Services are responsible for monitoring the atmospheric conditions related to weather as well as some parameters relating to ambient air quality. The monitoring and research activities conducted are part of the national effort to control and mitigate haze. The 1997/98 haze episode, and its subsequent effect on the people and the economy, prompted the introduction of more stringent measures by the government. The Environmental Quality Act (1974) was amended to provide stricter regulation and stiffer penalties to ensure, among others, the maintenance of air quality in the country. The Department of the Environment is the custodian to this. Furthermore, the monitoring and subsequent enforcement have been stepped up.

As an added measure, specific instruments were introduced including the zero burning policy, the National Haze Action Plan, and the Regional Haze Action Plan.

6.5.1 Enforcement of zero burning policy

Traditionally, open burning has been the cheapest, the most economical and practical means of land clearing, especially in the plantation sector. Unfortunately, the resultant fires caused severe pollution in the form of thick haze in the country, especially during the prolonged dry period during the El Nino years.

With the amendment of the Environmental Act (1974), zero burning was introduced as an alternative mechanism for the disposal of agricultural biomass. Through the amendment of the Act, open burning is prohibited except for such activities as may be proscribed by the Minister as published in the gazette. The penalty for contravening the low was substantially increased to RM 500,000 or imprisonment not exceeding 5 years, or both. In line with the stiffer penalties, enforcement activities were increased whereby ground enforcement teams were mobilized throughout the country to check on open burning activities. An operations 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 imagery detecting hot spots in the country for further enforcement action or other mitigating measures. For the period April to December 1998, a total of 495 cases of open burning were detected and investigated and follow-up actions were taken, including imposition of fines and prosecution. (Department of Environment 1999). This is one precautionary measure instituted to prevent haze formation in the country that was shown to be effective.

6.5.2 National Haze Action Plan (NHAP)

The National Committee on Haze formulated a revised Action Plan in 1997, with the following objectives:

- to prevent and control identified subsectoral activities which contribute to haze through better management policies and enforcement.
- to enhance operational mechanisms to monitor air quality, its reporting and dissemination of information.
- to strengthen intra-agency cooperation and support for detection, surveillance and combating haze.

Specifically, NHAP prescribes the operational procedures in response to different levels of API. Realization of the action plan depends very much on the inter-agency coordination especially in communication and data links between the Department of the Environment and relevant agencies such as the Ministry of Health, Police, local authorities and the Road Transport Department. Under the Action Plan, continuous preventive measures have been introduced to detect early outbreaks of fires, including aerial surveillance in fire prone areas such as in plantations, peat swamps, and construction sites. Formulation of national strategies and response plans to control and mitigate the impact of haze are undertaken by the National Haze Action Plan. However, once the API value reaches 300 and above, the Action Plan would be coordinated by the National Committee on Disaster Relief and Management (Department of Environment 1999).

6.5.3 Regional Haze Action Plan

Over the past two decades, the prolonged period of dryness brought about by a number of El Nino episodes, and the accompanying forest and plantation fires threatened the physical and economic well-being of a number of ASEAN member countries, especially Malaysia, Indonesia, Singapore and Brunei Darussalam. The resultant smoke from fires severely affected these countries. In response to these episodes, several national and international initiatives were instituted to deal with the transboundary pollution, culminating in the establishment of the Haze Technical Task Force (HTTF) in September 1995. The objectives of HTTF were to operationalize and implement the measures recommended by the ASEAN Cooperation Plan on Transboundary Pollution, including measures for addressing the problems of fire and smoke.

Following the 1997 regional haze episode, the HTTF developed a response strategy in the form of the Regional Haze Action Plan (RHAP), which was endorsed by the ASEAN Ministerial Meeting on Haze in December 1997. The plan is also supposed to complement and support the individual National Haze Action Plans. 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 for mechanisms that will enable authorities in the region to prevent fire, quickly spot those that occurred and take action to prevent them from spreading. Specifically, the objectives of the RHAP are to:

- prevent forest fires through improved management policies and enforcement.
- establish operational mechanisms for monitoring land and forest fires.
- strengthen regional land and forest fire fighting capability, and other mitigation measures.

In line with these objectives, RHAP identified three major components of activities and their respective coordinators as follows:

- Preventive measures (coordinated by Malaysia):
  Undertake activities related to aerial surveillance, training for fire fighters and training on zero burning technique.
- Regional monitoring (coordinated by Singapore):
  The activity is undertaken by the ASEAN Specialized Meteorological Center (ASMC), which is basically to provide updated information on fire hot spots in the ASEAN region and other relevant meteorological data. For example, ASMC acquired the National Oceanic and Atmospheric Agency (NOAA) satellite data reception and processing system in 1999, which boosted the early warning and surveillance system for the ASEAN region.
- Fire fighting capability (coordinated by Indonesia):
  The objective is to strengthen ASEAN's capacity to prevent and mitigate transboundary atmospheric pollution by inventoring the current fire repression resources in the region.

The implementation of RHAP was also supported by other international assistance such as the Asian Development Bank and the United Nation’s Environment Program. In cooperation with the Canadian Forest Service, ASEAN established the Fire Weather Information System to provide maps describing the on-time fire weather situation in the region, whilst Germany gave technical assistance through the Integration Forest Fire Management Project using multisensoral satellite images. To keep the public improved, ASEAN is maintaining a website at www.haze-online.or.id containing regular updates on the haze situation in the region (ASEAN 2001).

6.6 Other proactive measures

6.6.1 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 also helped in 'cleaning' the polluted air during the haze period. It involved the use of aircraft fitted with cloud seeding equipment. The aircraft fly into moderate size cumulus clouds over the catchment areas and spray very tiny (less than 10 microns) droplets of salt solution into the clouds to expedite the rain-formation process so that the clouds will rain over the targeted areas before moving away (Malaysian Meteorological Services 2001). Such operations have been carried out especially during the peak of El Nino episode when the water levels in the dams were critically low. Similar operations were conducted to improve the irrigated water supply in the MADA rice irrigation scheme. The operation has its own weaknesses in that the occurrence of rain in sufficient amount is not guaranteed, the rain might fall on areas outside the catchment areas or there may be no rain at all. The cost of the operation is also fairly high. In the National Haze Action Plan, cloud seeding was identified as one of the actions to be undertaken once the API index reaches 200 to 250.

6.6.2 Mobile water treatment plants

At the peak of the water crisis in Kuala Lumpur, ten mobile water treatment units were installed at a disused mining pool. This was to ease the acute water shortage in Kuala Lumpur. Even though these units could only treat about 4.4 million liters of water a day, it was a short-term measure which could help alleviate some of the problems related to water shortage.

7. Strategies and Recommendations

The earlier chapters have indicated the degree of impact due to the El Nino induced climate variation, particularly related to severe drought and haze. Whilst the country as a whole has already instituted some preventive and mitigating measures to reduce the impact, and to some extent, they have been shown to be effective and successful, much more should be done. In view of possible future El Nino events, the degree of preparedness so as to reduce as much as possible their impacts needs serious consideration. This chapter will highlight some of the possible strategies and recommendations, particularly those relevant to the agricultural sector.

7.1 Enhance R&D effort

R&D activities are critical in providing the technological support and possibilities of reducing the effects of El Nino induced climate change, especially in the agricultural sector. Special focus must be given to the following research areas:

- Towards enhancing the national predictive capabilities, an interaction between climate change, agricultural production and the relevant preventive and mitigating mechanisms must be established, such as in the form of an expert system and modeling.
- Research should continue on plant breeding and biotechnology for the development of varieties resistant to water stress and related technologies in view of the possible limitation of water available for agricultural purposes in the future.
- Research on the development of precision farming technology should be enhanced to ensure an efficient utilization of resources, especially water in crop production.
- Future variability in climate will most likely result in different sets of problems with regard to pests and diseases. An effective control method and preventive measures under an entirely different farm environment must be developed. Similarly, the changing of farm environments necessitates the development of related technologies for land and water management, crop management and post harvest management.
- Emphasis should continue on the development of water saving technology, including the possibility for greater utilization of recycled water, in view of the impending shortages in irrigation water in the future, especially during future El Nino episodes.
- There must be a concerted effort to critically isolate the effect of climate variability on agriculture through a standardized methodology. Such information is essential as part of the predictive and early warning system to be developed.
- In view of the fact that oil palm production was the most affected during the El Nino episodes, much more emphasis must be given on strengthening R&D activities on oil palm. Special focus must be given in establishing the relationship between crop growth and production with climate change. Similarly, breeding activities for drought and 'air pollution' resistance must be enhanced.

7.2 Improve national prediction capability

There is an urgent need to strengthen the national capacity and the capability to predict the impending threats brought about by climate variability and subsequent weather-related hazards. This capability must be extended to include forecasting capability for agricultural commodities based on the changing climatic environments, such as in the form of a simulation model or expert system. Such capability would not only enable prediction of forthcoming climate variation and possibly its magnitude and duration, but also enable forecasting its possible impact on agricultural production. Such information, coupled with information on marketing and pricing, would enable agricultural planners and farmers to make decisions about what crops to grow, where and how much in view of the impending climate change. The prediction would allow the agricultural industry to adjust itself (especially for the annual crops) in order to reduce its vulnerability to environmental stresses by specific management strategy. This should provide some lead time to prepare for the impending climate change. Such early warning mechanisms can contribute towards reducing the risk faced by farmers by adjusting their crop types and farm management to such climate change. Much can be gained, for instance, if El Nino episodes could be predicted well in advance, and possible impacts could be envisaged. Specifically, the following are suggested:

- Improve access to technical and financial resources to strengthen national scientific capability of the relevant departments and institutions to strengthen their monitoring and predictive capabilities. A bigger pool of scientists, research funds and facilities for research on environmental sciences and other relevant disciplines must be established as part of national capacity building.
- Establish a coordination and planning committee at the national level specifically to address issues related to climate variability and climate change. The committee could serve as a coordinating body to identify and mobilise national capacity to strengthen R&D activities in line with national priorities and needs. Additionally, the committee could support the existing IRPA (Intensification of Research in Priority Area) panel on Environmental Science in identifying and allocating R&D funds in relevant critical areas.
- Ensure greater commitments and support from established international centers in this area of expertise in providing the necessary expert advice and services. In this respect, current regional initiatives by the Global Change System for Analysis, Research and Training (START), Asia Pacific Network for Global Change Research, and World Climate Research Programme are welcome. However, the current involvement of Malaysian scientists within these regional initiatives must be strengthened to reflect our seriousness in this area of research. This would facilitate the information flow and sharing so optimal benefits could be derived. Whilst there are going to be problems normally associated with inter-country communication and cooperation, especially when it involves countries at different stages of capacity, it should not hinder efforts to strengthen regional and global cooperation. This could be translated into forms of training, joint projects, information sharing, etc.
- Strongly support the proposed Numerical Weather Prediction Center under the Malaysian Meteorological Services Department to strengthen the national weather prediction capability.

7.3 Upgrade water management capability

The existing water supply infrastructure and water storage and distribution system, particularly for agricultural proposes, has been fairly efficient. The adoption of various water conservation strategies is commendable. This is especially so for the efforts taken to ensure high irrigation efficiency through the application of various water saving technologies, including that of water recycling. Nevertheless, the degree of water wastage is still fairly high. Irrigation water, by virtue of its heavy subsidy, is cheap and since it is cheap, there is always a tendency to waste it. In this regard, and towards a long-term sustenance of water supply and availability, the following strategies are proposed:

- Introduce a new water pricing policy where the water resource is priced to reflect its scarcity value. This would ensure efficient utilization of water resources, especially the irrigation water.
- To further enhance water availability in a situation where there are not going to be new sources of irrigation water supply, the annual financial allocation by the government to maintain and improve the existing infrastructure so as to minimize further the water wastage during its distribution and utilization must be increased. This kind of 'investment' had not been given sufficient support in the past.
- The current activities related to farm level utilisation of recycled water must be continuously pursued, since it has been found to be effective in increasing the efficiency of water use.

7.4 Introduce drought action plan

Whilst drought incidence is not one of the major disasters facing the agricultural sector, the development of drought action plans would be helpful in time of severe drought incidence. The development of similar plans, such as the National Haze Action Plan, should be considered. The proposed plan should at least consist of the following elements:

- identification of drought prone areas.
- establishment of drought monitoring procedures, to improve prediction and degree of preparedness.
- establishment of a drought prevention program and response strategy.
- inclusion of insurance and government support strategies.
- identification of key players to realize the action plan.

7.5 Introduce contingency aid schemes for affected farmers

The previous El Nino episode caused adverse effects on some segments of the farm community. Specifically, the significant reduction in income received by oil palm growers because of the yield reduction, and the total wipeout of rice fields due to drought, albeit on small scale, warrant the introduction of some contingency plans. The following interventions are proposed:

- A government-sponsored scheme should be introduced to provide some aid to the affected farmers so as to protect their livelihood and welfare. It could be in the form of monetary aid or farm inputs.
- Crop insurance should be introduced to the farmers, especially in the El Nino vulnerable regions. This would enable the farmers to weather the effect on farm production and income due to climate abnormality.
- Based on the prediction of impending climate change, the government must be able to advice and implement mitigatory measures to be undertake at the farm level, even to the extent of changing the crop types. The alternative crops introduced must be supported in terms of the availability of planting materials, technology support, credit facilities and marketing outlets.

7.6 Strengthen regional cooperation

The establishment of the ASEAN Haze Action Plan by ASEAN member countries is a testimony to the possibility of collective effort in combating an environmental disaster at the regional level. The plan was very ambitious, comprehensive and covered all aspects of responsibilities and commitments among the member countries. Fairly frequent meetings were held to further strengthen and ensure its effectiveness. However, as with other regional collaboration efforts, there are areas which need further strengthening, as follows:

- Different levels of capability and capacity among the different member countries hinder the implementation or enforcement of decisions or agreements made at the regional level. Hence, continued upgrading is essential, including that of forest fire fighting capabilities.
- All barriers with respect to information and technology sharing related to climatic change should be abolished. In fact, more group efforts and pooling of resources must be pursued in order to step up preventive and mitigation measures.

7.7 Improve regional food security arrangement

Currently, there exists an ASEAN Buffer Stock for rice under the ASEAN food security arrangement program among ASEAN member countries. Under this program, member countries are committed to maintain a certain level of rice stock that is to be mobilized when requested by a member country that experiences severe rice shortages and finds difficulty to purchase rice in the normal world rice market. However, the rice still needs to be purchased at current market prices. The last El Nino episode clearly indicated that the El Nino effect was very much regional in nature, affecting almost the whole region, although at different degrees of intensity. The possibility of a much stronger El Nino affecting the whole region with greater adverse effect on food production should not be discounted. Hence, it is essential that the ASEAN Buffer Stock arrangement be reviewed, to take into consideration this possibility. The enhanced capacity in predicting such a disaster should be helpful to determine the right size of buffer stock that needs to be established.

8. Summary and Conclusions

This study has highlighted some of the El Nino induced weather variability that has taken place in the previous El Nino episodes. Generally, there was a significant reduction in rainfall, an increase in temperature regimes and a significant deterioration in air quality. This climatic variability has been shown to affect crop production. From the analyses carried out, there is strong evidence to show the negative effects of El Nino on Malaysian agriculture. The three most important commodities, oil palm, rubber and rice registered total losses amounting to RM 3.4 billion during the El Nino events in the last twenty years. Oil palm production constituted about 84% of these losses, followed by rubber (10%) and rice (6%). This represents direct production losses, and does not include other spin-off losses. In terms of foreign exchange loss, the loss in exports amounted to RM 2,129 for oil palm and RM 179 for rubber. The analyses for the other sub-sectors namely fruits, vegetables, sugar cane, fisheries and livestock products did not indicate a significant relationship between El Nino and productivity losses.

In view of the possible negative impacts of the abnormal weather, several programs have been put in place to either reduce or mitigate the effects of El Nino, particularly within the agricultural sector. These include the activities related to climate monitoring and forecasting, water resource management, research and development, national policy measures as well as regional collaboration and cooperation. These measures, to some extent, have been successful in combating some of the negative effects of El Nino induced abnormal weather. However, there is more that needs to be done. Definitely there is an urgent need to strengthen the national prediction capability particularly in predicting the impact of climate variability on crop production. Since water is going to be scarcer in the future, more affirmative action needs to be introduced to ensure more judicious use of water resources, including the possible introduction of a water pricing policy and more efficient use of water on the farm. Specifically for oil palm, there is a need to strengthen R&D efforts in the area of climate crop relationships and breeding activities for drought and air pollution resistance. Other recommendations include that of fostering closer regional cooperation, aid schemes for affected farmers, the need to enhance regional food security arrangements and to look into the possibility of introducing a drought action plan.

In conclusion, El Nino is here to stay. The possibility of increased frequency and magnitude in the future cannot be discounted. In addition, the impact on the economy as a whole, and on the agricultural sector specifically could be worse than in the past. It is pertinent now that more affirmative measures be introduced and implemented so that the impacts can be mitigated as much as possible, the sooner the better.

9. References

Abu, T.B.; Yew, F.K.; Mukhalis, B.; Naimah, I; Wan Mansor, W.S.; and Wong, C.B. 1990. Identification of Potential Rubber - Growing Areas and their Productivity in Malaysia. Report 1, pp 18.

Ahmad Zarin. 1997. Kursus Torehan Kekerapan Rendah, REACTORRIM dan RRIMFLOW.

Anon. 1993. Agroclimatic and crop zone classification in Malaysia. Malaysian Meteorological Services.

ASEAN. 2001. ASEAN Haze Action Online. http://www.haze-online.or.id. (August 2001).

Baker, J.T.; and Allen, Jr. L.H. 1993. Contrasting crop species responses to CO_2 and temperature: rice, soybean and citrus. Vegetatio 104/105:239-260.

Bjorkman, O. et al. 1980. Response and adaptation of photosynthesis to high temperatures. *In* Turner, N.C.; and Kramer, P.J. (eds.). Adaptation of Plants to Water and High Temperature Stress. pp 233-249.

Boyer, J.S. 1976. Water deficits and photosynthesis. *In* Kozlowski, T.T. (ed.). Water Deficits and Plant Growth. Vol. IV. Academic Press, New York. pp 153-190.

Boyer, J.S.; and Potter, J.R. 1973. Chloroplast response to low leaf water potentials. Plant Physio. 51:989-992.

Chamhuri Siwar. 1987. Rural Development Policies and Programmes in ASEAN. Institute of Southeast Asian Studies, Singapore.

Chan, A.K.; and Yap, K.S. 2000. National climate change scenarios. *In* Chong, A.L.; and Mathews, P. (eds.). Malaysia: National Response Strategies to Climatic Change. Min. of Science.

Chan, Y.K.; and Tay, T.H. 1982. Suitability of regions for fruit cultivation in Peninsular Malaysia. MARDI, Serdang, 49p.

Chong, A.L.; and Chan, A.K. 1994. Climate change in the East Asian Seas region. *In* Implication of expected climate change in East Asia Seas regions – An overview. Chow, L.M. (ed.). RCU/EAS Technical Reports Series No. 2.UNEP.

Chow, U.K.; and Lim, J.T. 1994. Monitoring of suspended particulates in Petaling Jaya. Urbanization and eco development with special reference to Kuala Lumpur. Institute of Advanced Studies, University of Malaya, pp. 178-185.

Corley, R.H.V. 1973. Midday closure of stomata in the oilpalm in Malaysia. Mardi Res. Bull 1:1-4.

Corley, R.H.V. 1976. Photosynthesis and productivity. *In* Oil Palm Research, Corley, R.H.V. Hardon, J.J.; and Wood, B.G. (eds) . Elsevier, Amsterdam, pp 55-76.

Dale, W.L. 1963. Surface temperatures in Malaya. J. Trop. Geog. 17:57-71.

Department of Agriculture. 1997. Review of the National Agricultural Policy (1996 – 2010), Chapter VI: Policy on Commodity Development (Crop Industry), Department of Agriculture Malaysia, Kuala Lumpur.

Department of Environment. 1999. Environment Management-Zero Burning. Ministry of Science, Technology and the Environment, Malaysia.

Doorenbos, J.; and Kassam, A.H. 1979. Yield response to water. Irrigation and Drainage Paper No. 33. FAO, Rome.

DOE. 2001. Department of Environments. http://www.mastic.gov.my/kstas (August 2001).

Economic Planing Unit, Malaysia, Prime Minster's Department. 1971. Second Malaysia Plan, 1971-1975, Government Press, Kuala Lumpur.

EEPSEA. 1998. Interim results of a study on the economic value of haze damages in South East Asia. http://www.idrc.org.sg/eepsea/haze.html. (August 2001).

Engku Aziz. 1964. Poverty and Rural Development in Malaysia. Kajian Ekonomi Malaysia 1(1).
Epstein, P.R. (ed.). 1999. Extreme Weather Events: The Health and Economic Consequences of the 1997-98 El Nino and La Nina, Boston, MA: Harvard Medical School and the Global Environment, 47 pp.
Fatimah Md. Yusoff. 1998. Effects of haze on the shrimp culture industry in Malaysia. National Symposium on Impact of Haze, 21 April, University Putra Malaysia.
Foong, K.C.; and Chiang, T.T. 1993. The weather factor in water management for padi cultivation in Muda area. *In* Proceedings of the Second National Seminar on Agrometeorology 1991. Petaling Jaya, Selangor, Malaysia, 11-12 June 1991, pp. 151-158.
Foster, H.L.; Malik, T.A.; Azmi, M.; Rashid, A.; and Ramli, M.N. 1981. Groundnut performance in the single rice crop areas of Peninsular Malaysia. Paper presented at the Seminar on the Management of Tropical Soils. Malaysian Society at Soil Science, March, Kuala Lumpur, 23 pages.
Gascho, G.J.; and Shih, S.F. 1982. Sugarcane. *In* Teare, I.D.; and Peet, M.M. (eds.) Crop Water Relations. Wiley Interscience. pages 393-473
Gill, H.S. 1962. Indian Jour. of Agronomy. Cited from Williams, C.N. and Joseph, K.T. 1981. Climate, soil and crop production in the humid tropics. Oxford Univ. Press, K.Lumpur.
Gommes, Rene. 1998. Climate-realated risk in agriculture. A note prepared for the IPCC Expert Meeting on Risk Management Methods, Toronto, Canada, 29 April – 1 May 1998.
Government of Malaysia. 2001. Eighth Malaysia Plan 2001-2005. Economic Planning Unit, Prime Minister's Department, Kuala Lumpur.
Government of Malaysia.1999. Mid-Term Review of the Seventh Malaysia Plan 1996-2000. Economic Planning Unit, Prime Minister's Department, Kuala Lumpur
Hacket, C.; and Carolane, J. 1982. Edible Horticultural Crops: A Compendium of Information on Fruit, Vegertable, Spice and Nut Species. Academic Press, Sydney, New York. 673pp.
Haridas, G. 1980. Soil moisture use and growth of young Hevea Brasiliensis as determined from lysimeter studies. J. Rubb. Res. Inst. Malaysia 28(2):49-60.
Hartley, C.W. S. 1977. The Oil Palm. Longman, pp. 806.
Henderson-Sellers, A.; and Hansen. 1995. Climate change atlas.
Hishamuddin, O.; Fatimah, M.Y.; Misri, K.; Idris, a.G. Syed Ahmed Khan; and Abu Hena, M.K. 1998. The effects of haze to the aquatic ecosystem: A review. National Symposium on the Impact of Haze, 21 April, Universiti Putra Malaysia.
Hsiao, T.C. 1973. Plant responses to water stress. Ann. Review Plant Physiology 24:519-570.
Imai, K.; and Murata, Y. 1976. Effect of carbon dioxide concerntration on growth and dry matter production in crop plants. 1. Effects on leaf area, dry matter, tillering, dry matter distribution ratio, and transpiration. Jpn. J. Crop. Sci. 45:598-606.
Intergovernmental Panel on Climate Change (IPCC). 1995. Climate Change 1995: The Science of Climate Change. Houghton, J.T.; Meira Filho, L.G.; Callander, B.A.; Harris,N.; Kattenberg, A.; and Maskell, K. (eds). Contribution of working Group I to IPCC Second Assessment Report. Cambridge Univ. Press, Cambridge, U.K. 572 pp.
IRRI 1970. Annual Report. IRRI, Los Banos, Philippines, pp. 148-150.
Jackson, I.J. 1989. Climate, Water and Agriculture in the Tropics 2nd ed. Longman, London.
Jalani Sukaimi; and Malek Mansoor. 1995. Support policies for the Malaysian oil palm industry. Paper read at the FEDEPALMA International Conference, Barranquilla, Colombia.
Jegatheesan; and Yasunobu, K. 1996. Muda Agricultural Development Authority and Japan International Research Center for Agricultural Sciences, Alor Setar, Kedah.
Jones, H.G.; and Higgs, K.H. 1989. Empirical models of the conductance of leaves in apple orchards. Plant, Cell and Environment 12:301-308.

Kimberly, A. 1995. El Nino and the Southern Oscillation: A Reversal of Fortune. Graduate Thesis, University of Massachusets.

Kozlowski, T.T. 1968. Water Deficits and Plant Growth. Vol. I. Development, Control and Measurement. Academic Press, New York

Kraalingen, D.W.G.; Van Breure, C.J.; and Spitters, C.J.T. 1989. Simulation of oil palm growth and yield. Agric. for Meteorology 46: 227-244.

Kramer, P.J.; and Kozlowski, T.T. 1979. The Physiology of Trees. McGraw-Hill, NewYork. 642p.

Larcher, W. 1995. Physiological Plant Ecology. Springer-Verlag, New York. 506 p.

Lim, J.T. 1998. ENSO and its relationship to haze and forest fire in Southeast Asia. Malaysian Meterological Services, Petaling Jaya, Selangor.

Lim, J.T.; and Ooi, S.H. 1998a. Effects of biomass burning in Southeast Asia on meteorological condition in Malaysia. Paper read at the Conference on Weather Analysis and Forecasting, Taipei, Republic of China, 23-25 February.

Lim, J.T.; and Ooi, S.H. 1998b. Impact of extreme climatic phenomena on water resources management in Malaysia. Paper read at Seminar on Water, Forestry and Land Use Perspectives. Forest Research Institute, Malaysia, 31 March -1 April.

Malaysia Metereological Services. 2001. http://www.kjc.gov.my (August 2001).

Malaysia Rubber Board. 2001. http://www.lgm.gov.my (August 2001).

Malaysian Palm Oil Board. 2001. http://www.mpob.gov.my (August 2001).

MARDI. 1993: MARDI Technical Report, MARDI, Serdang, Selangor.

MARDI. 2001. http://www.mardi.my (August 2001).

Matsushima. 1962. Proc. Crop Sci. Soc. Japan 31:115-121.

May, L.H.; Milthorpe, E.J.; and Milthorpe, E.L. 1962. Pre-sowing hardening of plants and drought. An appraisal of the contribution by P.A. Henkel. Field Crop Abstr. 15:193-198.

Mazrura, S. 1998. The impacts of haze on human health. National symposium on Impact of Haze, 21st. April 1998, Universiti Putra Malaysia.

Mearns, L.O.; Rosenzweig, C.; and Goldberg, R. 1996. The effect of changes in daily and interannual climatic variability on CERES-wheat: A sensitivity study. Climatic Change 32: 257-292.

Ministry of Agriculture, Malaysia. 1999. Third National Agricultural Policy (1998-2010), Ministry of Agriculture, Malaysia, Kuala Lumpur.

Mintier, T. 1997. El Nino adds to woes of haze-plagued Malaysia. http://www.cnn.com/WEATHER/9710/14/el.nino.haze (August 2001).

Mohamad, A.B.; and Yew, F.K. 1991. Climatic change and their effects on Hevea Brasiliensis. *In* Proceedings of the Second National seminar on Agrometeorology 1991. Petaling Jaya, Selangor, Malaysia, 11-12 June 1991, pp. 151-158.

Mohd Arif Simeh; and Tengku Ariff Tengku Ahmad. 2001. Commodity Export Diversification and Poverty Reduction: The Case of the Malaysian Palm Oil. Paper read at the UNCTAD/ESCAP Regional Workshop on Commodity Export Diversification and Poverty Reduction, Bangkok, 3-5 April.

Mohd Nasir, H.; Muhamad, A.; Mohd Shahwahid, H.; and Mohd Azahar, A. 1998. The damage costs of haze episodes in Malaysia. National Symposium on the Impact of Haze, 21 April 1998, Universiti Putra Malaysia.

Mohd Nasir, H.; Muhamad, A.; Rajan, S.; Ahmad Makmom, A.; Dzulkifly, K.; Wan Zin, WY.; Ramzani, A.; Mohd Pauzi, Z.; Theng, L.C.; and Abu Bakar, J. 1999. The economic impacts of the 1997 haze episode on the agricultural sector. Proc. of Seminar on Repositioning Agriculture Industry in the Next Millennium. UPM.

Mohd Shahwahid Haji Othman; Mohd Nasir Hassan; and Jamal Othman. 1998. The damage cost of the haze in Malaysia. Paper read at the National Symposium on Impact of Haze, Universiti Putra Malaysia, 21 April.

Mohd Sukri Haji Abdullah. 1992. Strategy Pembangunan Desa Semenanjung Malaysia. Dewan Bahasa dan Pustaka, Kuala Lumpur.

Monteith, J.L. 1981. Climatic variation and the growth at crops. Quart. J.R. Met. Soc. 107:749-774.

Nickell, L.G. 1969. Water utilization. I. Basic plant water studies. Proc. Congr. Int. Soc. Sugar Cane Technology, 13th, pp. 38-48.

Nickell, L.G. 1974. Sugarcane. *In* Alvim, P. de T.; and Kozlowski, T.T. (eds) Ecophysiology of Tropical Crops. Acdemic Press. pp. 89-111.

Nieuwolt, S. 1982. Climate and Agricultural Planning in Peninsular Malaysia. Special Report No, ASAS-01-83, MARDI, Serdang, Malaysia.

Nieuwolt, S. 1982. Climates and Agricultural Planning in Peninsular Malaysia, Special Report No. ASAS-01-83, Malaysian Agricultural Research and Development Institute MARDI, Serdang, Selangor.

Nieuwolt, S.; M. Zaki Ghazalli; and Gopinathan, B. 1982. Agro-ecological regions in Peninsular Malaysia. Malaysian Agricultural Research and Development Institute MARDI Serdang, Selangor.

Nishiyama, I. 1976. Effects of the temperature on the vegetative growth of rice plants. *In* Climate and Rice. International Rice Research Institute, Los Banos, Philipphines, pp. 159-185.

Norby, R.J.; and O'Neill, E.G. 1989. Growth dynamics and water use of seedlings of Quercus alba L. in CO_2-enriched atmosphere. New phytologist 111:491-500

Nordin, M.M.; Sheikh-Omar, A.R.; Rosley, M.S.; Tan, C.C.; and Saad, M.Z. 1998. Impact of haze on animal health and production. National Symposium on Impact of Haze, 21 April, Universiti Putra Malaysia.

Oberbauer, S.F.; Strain, B.R.; and Fetcher, N. 1985. Effect of CO_2-enrichment on seedling physiology and growth of two tropical tree species. Physiol. Plant 65:352-356.

Penning de Vries, F.W.T. 1993. Rice production and climate change. *In* Penning de Vries, F.W.T.; Teng, P.; and Metselaar, K. (eds.) System Approaches for Agricultural Development. Kluwer/IRRI. pp 175-189.

PORIM. 1994. Risalah Sawit: Pengurusan Air di Ladang Kelapa Sawit, pp., 4.

Potulski, N. 1990. Effect of soil and atmospheric drought on leaf gas exchange rates of plantation palms. PhD thesis, University of Cambridge, U.K.

Ramadasan, K.; Mohd Zabawi Abul Ghani; Yew, F.K.; Mohd Yusoff Abdullah; and Hawa Z. Jaafar. 2000. Assessment of, and adaptation to, the potential impact of climatic change on agriculture in Malaysia. *In* Chong Ah Look; and Philip Mathews, (eds) Malaysia UNDP/GEF Project: National Response Strategies to Climate Change. Ministry of Science and Technology, pp. 255-302.

Raymond, G.; Tan, S.; and Awang, M.H. 1997. Commercial experience in tree plantation establishment. Seminar on Commercial Cultivation of Teak, Sentang, Acacia and Hevea for Timber. Kuala Lumpur, pp. 8.

Rogers, H.H.; and Dahlman, R.C. 1993. Crop responses to CO_2 enrichment. Vegetatio 104/105:117-131

Salter, P.J.; and Goode, J.E. 1967. Crop responses to water at different stages of growth. Commonwealth Agricultural Bureau, England.

Satake, T.; and Yoshida, S. 1978. High temperature induced sterility in indica rices at flowering. Jpn. J. Crop. Sci. 47: 6-17.

Seidel, K.W. 1972. Drought resistance and internal water balance of oak seedlings. Forest Sci. 18: 34-40.

Sekhar, B.C. 2000. The Malaysian plantation sector: rubber, oil palm – the new millennium equation. Paper read at the Eminent Person Lecture, Academy of Science Malaysia, Kuala Lumpur.

Seshu, D.V.; and Cady, F.B. 1984. Response of rice to solar radiation and temperature estimated from international rice trials. Crop Sci. 24: 649-654.

Sethuraj, M.R.; and Raghavendra, A.S. 1987. Rubber. *In* Sethuraj, M.R.; and Raghavendra, A.S. (eds.) Tree crop physiology. Elsevier. pp. 193-223,

Sham Sani. 1998. The environment. *In* Encyclopedia of Malaysia, Kuala Lumpur.

Singh, S.; Amartalingam, R.; Wan Harun, W.S.; and Islam, M.T. 1996. Simulated impact of of climate change on rice production in Peninsular Malaysia. Proceeding of National Conference on Climate Change. UPM, pp. 41-49.

Sivakumaran 1997. Cabaran teknologi exploitasi terkini. Seminar Pengurusan Espek; pp. 16.

Sivalingam, G. 1994. Productivity and equity impact of water allocation policy in Malaysia. *In* Agricultural Sustainability, Growth, and Poverty Alleviation in East and Southeast Asia: Issues and Policies. Rosegrant, Mark W.; Witcover, Julie; Gerpacio, Roberta V.; Ringler, Claudia (eds.) Kuala Lumpur 3-6 Oct 1994.

Slatyer, R.O. 1967. Plant Water Relations. Academic Press, New York.

Smith, B.G. 1989. The effect of soil water and atmospheric vapour pressure deficiton stomatal behaviour and photosynthesis in the oilpalm. Jour. Expt. Botany 215:647-651.

Squire, G.R. 1990. The Physiology of Tropical Crop Production. CABI, Wallingford, U.K.

Steponkus, P.L.; et al. 1980. Adaptation to water stress in rice. *In* Turner, N.C.; and Kramer, P.J. (eds.) Adaptation Wiley-InterSceince, New York, pp 401-418.

Sys, C.; van Ranst, E.; Debaveye, J.; Beemaert, F. 1993. Land Evaluation: Part 111. Crop Requirements

Tashiro, T.; and Wardlaw, I.F. 1989. A comparison of the effect of high temperature on grain development in wheat and rice. Ann. Bot. 64:59-65.

Tengku Mohd Ariff Tengku Ahmad; and Ariffin Tawang. 1999. Effects of Trade Liberalization on Agriculture in Malaysia: Commodity Aspects.Working Paper No. 46, CGPRT Centre, Bogor, September.

Turner, F.T.; and McCauley, G.N. 1983. Rice. *In* Teare, I.D. and Peet, M.M. (eds.) Crop Water Relations. Wiley Interscience. pages 393-473

United Nations. 2000. Lessons from the 1997-98 El Nino: Once burned, twice shy? United Nations University, Tokyo.

Wheeler, T.R.; Ellis, R.H.; Hadley, P.; Morison, J.I.L.; Batts, F.R.; and Daymond, A.J. 1996. Assessing the efferts of climate change on field crop production. Aspects of Applied Biology No. 45, 49-54.

Wigley, T.M.L. 1985. Impact of extreme events. Nature 316:106-107.

Wilhite, D.; and Glantz, M.R. 1987, Understanding the drought phenomenon-The role of definitions. *In* Wilhite, D., Easterling, W., and Wood, D. (eds.) Planning for Drought. Boulder, Colo., Westview Press, p. 11-27.

Williams, C.N.; and Chew, W.Y. 1979. Trees and field crops of the Wettest Regions of the Tropics. Intermediates Tropical Agric. Series, 197.

Wong, N.C.; and Mohamad Zabawi, A.G. 1990. Soil and weather suitability for orchard farming in the east cost state of Kelantan, Terengganu and Pahang. Paper presented at Seminar On Prospects of Integrated farming in East Cost, 27 Sept 1990, Kuantan.

World Health Organization. 1998. Report on the Bioregional Workshop on Health Impacts of Haze Related Air Pollution. Kuala Lumpur. 1st - 4th.

Yew, F.K. 1982. Contribution towards the development of a land evaluation system for Heyea Brasiliensis muell. Aerg cultivation in Peninsular Malaysia. Dr. Sc. thesis, State University Ghent, Belgium. pp 329.

Yew, F.K. 1990. Influence of drought on Hevea performance. Report submitted to Director, Rubber Research Institute of Malaysia.

Yew, F.K. 1998. Unpublished data.

Yew, F.K.; and Sys, C. 1990. An evaluation system of climate suitability for Hevea Brasiliensis cultivation. Nat. Sem. on land Evaluation, Kuala Lumpur.

Yew, F.K.; Haridas, G.; Nordin, W.D.; Chan, H.Y.; and Raveendran, N. 1987 Land allocation and productivity of Malaysian natural rubber up to the year 2009. Proc. Rubber Research Inst. Malaysia Rubb. Grow. Conf. Ipoh 1986, 22.

Yoshida, S. 1981. Fundamentals of Rice Crop Science. International Rice Research Institute, Los Banos, Phillipines. 270 p.

Yoshida, S.; and Parao, F.T. 1976. Climatic influences on yield and yield components of lowland rice in the tropics. *In* Proc. of the Sym. on Climate and Rice, International Rice Research Institute, Los Banos, Philippines: 471-494.

Yoshida, S.; and Hara, T. 1977. Effects of air temperature and light on grain filling of an indica and japonica rice Oryza sativa, L. under controlled environmental conditions. Soil. Sci. Plant Nutr. 23:93-107.

Ziska, L.H.; Namuko, O.; Moya, T.; and Quilang, J. 1997. Growth and yield response of field-grown tropical rice to increasing CO_2 and air temperature. Agronomy Journal 89:45-53.

APPENDIX 1: Estimated Regression Coefficients for Oil Palm, Rubber and Rice

Function:

LnYt = f(RFt-1, TSPt-1, TEMPt-1, YEARt, DUM, DUM*RF)

where:			
	LnYt	=	natural log of average annual yield in year t,
	RFt	=	average monthly rainfall in year t,
	TSPt	=	average monthly total suspended solids in the atmosphere in year t;
	TEMPt	=	average monthly temperature in year t;
	YEARt	=	time trend variable as a proxy for technological advancements
	DUM	=	Dummy, 1 for the El Nino Years (1981, 1982, 1990, 1997, and 1998) and 0 otherwise
	DUM*RF	=	Dummy-rainfall interactive variable

a. Oil palm

VARIABLE NAME	ESTIMATED COEEFICIENT	STANDARD ERROR	T-RATIO 12 DF	PARTIAL P-VALUE CORR.	STANDARDIZED COEEFISIENT	ELASTICITY AT MEANS
YEAR	-0.14015E-02	0.3444E-02	-0.406	0.691-0.117	-0.0845	-2.1503
TEMP	-0.28780	0.1004	-2.868	0.014-0.638	-0.9137	-5.9574
RAINFALL	-0.71902E-03	0.1135E-02	-0.6337	0.538-0.180	-0.1575	-0.1206
TSP	0.82159E-02	0.2664E-02	3.085	0.009 0.665	0.6656	0.2982
DUM	-2.2243	0.7873	-2.825	0.015-0.632	-10.7858	-0.4513
DRAIN	0.10903E-01	0.3944E-02	2.765	0.017 0.624	10.3692	0.4326
CONSTANT	11.607	4.851	2.392	0.034 0.568	0.0000	8.9490
R-SQUARE =	0.6785	R-SQUARE ADJUSTED =		0.5177	DURBIN-WATSON =	2.0816

b. Rubber

VARIABLE NAME	ESTIMATED COEEFICIENT	STANDARD ERROR	T-RATIO 13 DF	PARTIAL P-VALUE CORR.	STANDARDIZED COEEFISIENT	ELASTICITY AT MEANS
YEAR	-14.736	10.20	-1.444	0.172-0.372	-1.1049	1667.6183
TEMP	-19.964	81.84	-0.2439	0.811-0.067	-0.0730	30.4911
RAINFALL	-0.92265E-01	0.7832	-0.1178	0.908-0.033	-0.0241	1.1485
TSP	4.0587	2.734	1.484	0.162 0.381	0.3907	10.7695
DUM	-916.93	436.7	-2.100	0.056-0.503	-5.1627	13.0394
DRAIN	4.9165	2.232	2.203	0.046 0.521	5.4292	-13.6727
CONSTANT	29589.	0.2004E+05	1.476	0.164 0.379	0.0000	-1683.1351
DURBIN-WATSON = 1.3268		R-SQUARE =	0.5802	R-SQUARE ADJUSTED =		0.3865

c. Rice

VARIABLE NAME	ESTIMATED COEEFICIENT	STANDARD ERROR	T-RATIO 13 DF	PARTIAL P-VALUE CORR.	STANDARDIZED COEEFISIENT	ELASTICITY AT MEANS
YEAR	0.15118E-01	0.5049E-02	2.994	0.010 0.639	0.6854	30.5826
TEMP	0.10826	0.6467E-01	1.674	0.118-0.421	0.2393	2.9559
RAINFALL	-0.12657E-02	0.6179E-03	-2.049	0.061-0.494	-0.2000	-0.2816
TSP	-0.19024E-02	0.2148E-02	-2.283	0.040-0.535	-0.2853	-0.2325
DUM	0.56591	0.3464	1.634	0.126 0.413	1.9267	0.1439
DRAIN	-0.30784E-02	0.1769E-02	-1.740	0.105-0.435	-2.0556	-0.1530
CONSTANT	-31.497	9.677	-3.255	0.006-0.670	0.0000	-32.0269
R-SQUARE =	0.9170	R-SQUARE ADJUSTED =		0.8787	DURBIN-WATSON = 1.3809	