# Economic costs of drought and rice farmers' coping mechanisms

Edited by S. Pandey, H. Bhandari, and B. Hardy

IRRI

# Economic costs of drought and rice farmers' coping mechanisms:
## a cross-country comparative analysis

**Edited by**
S. Pandey, H. Bhandari, and B. Hardy

2007

IRRI

INTERNATIONAL RICE RESEARCH INSTITUTE

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today, IRRI is one of the 15 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR – www.cgiar.org).

IRRI receives support from the following CGIAR members: Australia, Asian Development Bank, Canada, Denmark, European Commission, Food and Agriculture Organization of the United Nations, France, Germany, India, International Fund for Agricultural Development, Iran, Japan, Malaysia, Netherlands, Norway, People's Republic of China, Republic of Korea, Republic of the Philippines, Rockefeller Foundation, Sweden, Switzerland, Thailand, United Kingdom, United States, Vietnam, and World Bank. Additional support comes from several civil society organizations and the private sector.

The responsibility for this publication rests with the International Rice Research Institute.



**Mailing address:** DAPO Box 7777, Metro Manila, Philippines
**Phone:** +63 (2) 580-5600
**Fax:** +63 (2) 580-5699
**Email:** irri@cgiar.org
**Web:** www.irri.org.
**Rice Knowledge Bank:** www.knowledgebank.irri.org
**Courier address:** Suite 1009, Security Bank Center
6776 Ayala Avenue, Makati City, Philippines
Tel. +63 (2) 891-1236, 891-1174, 891-1258, 891-1303

**Suggested Citation:**
Pandey S, Bhandari H, Hardy B, editors. 2007. Economic costs of drought and rice farmers' coping mechanisms: a cross-country comparative analysis. Los Baños (Philippines): International Rice Research Institute. 203 p.

Cover design: Juan Lazaro IV
Page makeup and composition: George Reyes
Figures and illustrations: Emmanuel Panisales and Eileen Tolentino
Cover photo: Ram Cabrera

**ISBN 978-971-22-0212-4**

# Contents

# Foreword

Addressing the problems of poverty, hunger, poor health, and environmental degradation is now firmly on the agenda of international development agencies and national governments. IRRI's new Strategic Plan 2007-2015, *Bringing Hope, Improving Lives,* has the goals of reducing poverty, food insecurity, and environmental degradation as its centerpiece. A key strategy of IRRI to achieve these goals is to develop improved technologies that produce higher and more stable yields in the face of frequently occurring abiotic stresses such as drought and submergence that adversely affect rice production in large areas.

Drought is a major constraint affecting rice production, especially in rainfed areas across Asia and sub-Saharan Africa. At least 23 million hectares of rainfed rice area (20% of total rice area) in Asia are estimated to be drought-prone. Even in traditionally irrigated areas, which account for almost 75% of total rice production, drought is becoming an increasing problem because of water scarcity resulting from rising demand for water for competing uses. Drought imposes a serious economic burden on society and has been historically associated with food shortages of varying intensities, including those that have resulted in major famines in different parts of Asia and Africa.

The impact of drought on poverty is very direct. Poor farmers lose both whatever meager investment in food production they have made and the food needed desperately for their and their family's sustenance. As the opportunities for farm and other rural employment disappear because of production losses, so does the income of laborers who rely on these sources of employment for their wage income. Millions of poor people who lie perilously just above the poverty line fall back below it because of drought-induced income losses. Others already below the poverty line in normal years are pushed farther down the poverty ladder. If drought occurs in consecutive years, which happens too frequently, the situation becomes quite desperate. As farmers go into debt, pull children out of school, and liquidate their productive assets—such as bullocks, farm implements, and even land—they get trapped even deeper in poverty, from which escape becomes more and more difficult. Thus, the effects of drought may be felt over several years and its impact can span generations as children fail to recoup lost educational opportunities.

The economic costs of drought in the rice-based systems of Asia are substantial and include not only the obvious losses in production but also the hidden costs incurred by farmers while attempting to cope with the adverse economic consequences. These costs and economic consequences vary across countries, depending on the nature of rice production systems, levels of economic growth, and institutional and policy contexts. A sound knowledge of the nature of drought in rice production systems, its economic costs, and farmers' coping mechanisms is needed to effectively design technological and policy interventions for achieving long-term drought mitigation. This cross-country comparative study of the economic costs of drought and rice farmers' coping mechanisms, based on three major rice-growing countries of Asia, clearly reveals valuable new insights that, I am sure, will be useful to researchers and policymakers alike.

ROBERT S. ZEIGLER
Director General

# Acknowledgments

We would like to acknowledge several organizations and individuals who have directly or indirectly contributed to the completion of this research work and publication of this book. This research work was made possible through a financial grant from the Rockefeller Foundation. Dr. John O'Toole, former associate director of the Rockefeller Foundation, inspired this study. Furthermore, his valuable suggestions helped improve the quality of the research work.

This book is a product of collaborative research work implemented in three countries, India, Thailand, and China. The International Rice Research Institute (IRRI) collaborated with three universities in India, Indira Gandhi Agricultural University (IGAU) in Chattisgarh, Orissa University of Agriculture and Technology (OUAT) in Bhubaneshwar, and Ranchi University (RU) in Ranchi. IRRI likewise collaborated with Khon Kaen University in Khon Kaen and with Zhongnan University of Economics and Law in Wuhan for implementation of the study in Thailand and China, respectively. The team in China received additional financial support from the National Natural Sciences Foundation in China.

In India, we would like to thank the staff of IGAU, OUAT, and RU for their support and cooperation in the conduct of the project. In Thailand, thanks are due to Khon Kaen University for the research support provided by its staff and for the use of university facilities. We would also like to thank the Department of Meteorology for providing rainfall data and the Departments of Agriculture and Agricultural Extension of the Ministry of Agriculture and Cooperatives for providing national and local statistics.

In China, we acknowledge technical support from Dr. Zhang Qifa (academician of the Chinese Academy of Sciences) of the Huazhong Agricultural University; Dr. Luo Lijun, Mr. Gu Xiaojun, Mr. Yu Xinqiao, and Mr. Mei Hanwei of the Shanghai Agrobiological Gene Center; Mr. Yang Wanjiang from Zhejiang University; and Dr. Chen Yuping from the Zhongnan University of Economics and Law. Officials from the study provinces provided support for field work. Their assistance is explicitly acknowledged in the chapter on China.

We thank Dr. Mahabub Hossain, Head of the Social Sciences Division, IRRI, for his support and valuable suggestions throughout this study. We recognize gratefully the hard work and efforts of Lourdes Velasco of the Social Sciences Division of IRRI for her contributions in the research design, data management and analysis, and publication of this book. The assistance of Aileen Lapitan, Christina Obusan, Frederick Lagasca, Aladin Poblete, Josie Narciso, Lydia Damian, and Mirla Domingo of IRRI is also acknowledged. We thank the staff of IRRI's Communication and Publications Services, who helped with the graphic design and the staff of IRRI's Geographic Information Systems Laboratory for providing the maps.

We are most grateful to Prof. Dr. C.H. Hanumantha Rao, former member of the Planning Commission, Government of India, for his contributions throughout the study and for a careful review of the manuscript. His valuable comments and suggestions helped improve the analytical content. We would also like to express our thanks to all those who participated in the final workshop of this research project and provided feedback to improve the quality of the output.

Finally, we are thankful to the 1,316 farmers who provided their time and valuable information on which this work is based.

CHAPTER 1
# Introduction

S. Pandey and H. Bhandari

## 1. Background

Climate-related natural disasters (droughts, floods, and typhoons) are the principal sources of risk and uncertainty in agriculture. The wide fluctuations in agricultural output that have occurred throughout human history attest to the fact that agriculture is an economic activity dependent on the vagaries of weather. Although attempts have been made to reduce the adverse effects of weather on agriculture through scientific research and technology development, the performance of agriculture still depends largely on the weather.

Rice is the staple crop of Asia. Although the production of rice has increased over time in the wake of the Green Revolution, major shortfalls caused by climatic aberrations such as drought and flood are frequent. Drought is one of the major constraints to rice production in Asia. At least 23 million ha of rice area (20% of total rice area) are drought-prone (Table 1.1). India accounts for the largest share (59%) of the total drought-prone rice area in Asia. Most of these drought-prone areas are rainfed.

The economic costs of drought can be enormous. For example, drought has been historically associated with food shortages of varying intensities, including those that have resulted in major famines in different parts of Asia and Africa. In India, major droughts in 1918, 1957-58, and 1965 resulted in famines during the 20th century (FAO 2001). The 1987 drought affected almost 60% of the total cropped area and 285 million people across India (Sinha 1999). Similarly, the average annual drought-affected area in China during 1978-2003 was estimated to be 14 million ha and the direct economic cost of drought was estimated to be 0.5–3.3% of the agricultural sector GDP.[1] In 2004, a severe drought hit many countries in Southeast Asia and caused shriveling of crops on millions of hectares, costing millions of dollars, shortages of water for drinking and irrigation, and suffering of millions of people. In Thailand, the drought of 2004 was estimated to have affected 2 million ha of total cropped area and over 8 million people (Bank of Thailand 2005, Iran Daily 2005, BBC News 2005, Asia Times 2005).

[1]This range is derived from various sources, which are listed in Table 6.1.

**Table 1.1. Drought-prone rice area in Asia (million ha).**

| Country | Rice area[a] | | Drought-prone rice area | |
|---|---|---|---|---|
| | UR | RL | UR[b] | RL[c] |
| India | 6.3 | 16.0 | 6.3 | 7.30 |
| Bangladesh | 0.9 | 6.0 | 0.9 | 0.80 |
| Sri Lanka | 0.06 | 0.2 | – | n.a. |
| Nepal | 0.1 | 1.0 | 0.1 | 0.27 |
| Myanmar | 0.3 | 2.5 | 0.3 | 0.28 |
| Thailand | 0.05 | 8.0 | – | 3.10 |
| Laos | 0.2 | 0.4 | 0.2 | 0.09 |
| Cambodia | – | 1.7 | – | 0.20 |
| Vietnam | 0.5 | 3.0 | 0.5 | 0.30 |
| Indonesia | 1.1 | 4.0 | 1.1 | 0.14 |
| China | 0.6 | 2.0 | 0.6 | 0.50 |
| Philippines | 0.07 | 1.2 | – | 0.24 |
| Total | 10.0 | 46.0 | 10.0 | 13.00 |

[a]Source: IRRI (1997). [b]Assuming all upland rice (UR) area as drought-prone. [c]Source: Mackill et al (1996). Rainfed lowland (RL) rice area is classified as drought-prone and drought- and submergence-prone. The numbers represented in the table provide lower-bound estimates as the drought-prone and submergence-prone areas are excluded.

Drought can have a multidimensional effect on human societies. Its effect in terms of production losses and consequent human misery is well publicized during years of crop failure. However, losses to drought of milder intensity, although not so visible, can be substantial. Production losses, which are often used as a measure of the cost of drought, are only a part of the overall economic cost. Severe droughts can result in starvation and death of the affected population. However, different types of economic costs arise before such severe consequences occur. Because of market failures, farmers attempt to "self-insure" by making costly adjustments in their production practices and adopting conservative practices to reduce the negative impact during drought years. Although these adjustments reduce direct production losses, they themselves entail some economic costs in terms of opportunities for income gains lost during good years.

The loss in agricultural output is not the only consequence of drought. In rural areas where agricultural production is the major source of income and employment, a decrease in agricultural production will set off second-round effects through forward and backward linkages of agriculture with other sectors. A decrease in agricultural income will reduce the demand for products of the agro-processing industry that caters to local markets. This will lead to a reduction in income and employment in this sector. Similarly, the income of rural households engaged in providing agricultural inputs will also decrease. This reduction in household income will set off further "knock-on" effects. By the time these effects have been fully played out, the overall economic loss from drought may turn out to be several times more than what is indicated by the loss in production of agricultural output alone. The loss in household income can result in a loss in consumption of the poor, whose consumption levels are already low. Farmers may cope with the loss by liquidating productive assets, pulling children out of school, migrating to distant places in search of employment, and going deeper into debt. The economic and social costs of all these consequences can indeed be enormous.

Much of the current knowledge on drought is based mainly on arid and semiarid regions (Jodha 1978, Campbell 1999, Hazell et al 2001, Shivakumar and Kerbart 2004, Rathore 2004). Despite reasonably high rainfall, drought occurs frequently in the subhumid regions of Asia (Table 1.2). Rainfed rice-growing areas in subhumid tropics have low agricultural productivities and are the major "poverty hotspots." The nature and frequency of drought in subhumid regions, its impact on farmers' livelihoods, farmers' drought-coping strategies, and the welfare implications of drought have not been adequately studied. Analyses of drought characteristics, drought impacts, and household coping mechanisms are important for understanding the nature of risk and vulnerability associated with drought and for formulating various interventions for effective drought mitigation. This book attempts to examine these issues through a cross-country comparative study of the impact of drought and farmers' coping mechanisms. The countries included in the study are China, Thailand, and India. These countries vary in climatic conditions, level of economic development, rice yield, and institutional and policy contexts of rice farming. Comparative analyses of the impact of drought and responses from these varying conditions can provide better insights than studies of individual countries conducted separately.

## 2. Objectives

The main objective in this study is to estimate the economic costs of drought in the major rice-growing countries of Asia, document farmers' risk-coping mechanisms in drought-prone rice-growing areas of Asia, and recommend suitable interventions, both technological and policy, for effective drought management. The specific objectives of the study are as follows:

1. To understand the nature and magnitude of drought risk in drought-prone rice-growing areas of Asia,
2. To estimate the economic costs of drought at the aggregate level,
3. To estimate the economic costs of drought at the farm-household level, and analyze farmers' drought-coping mechanisms,
4. To analyze the impact of drought on poverty, and
5. To suggest alternative options for technology and policy interventions for the effective management of drought.

## 3. Outline of the report

This book is organized into seven chapters. It begins with a general discussion of the drought problem in the rainfed rice production system in South and Southeast Asia and the objectives of the study. Chapter 2 presents a literature review about the definition, economic costs, and coping mechanisms for drought. Chapter 3 describes

**Table 1.2. Frequency of drought in the Asia-Pacific region, 1950-2005.**

| Country | Occurrence of drought during | | | Drought probability |
|---|---|---|---|---|
| | 1950-70 | 1971-90 | 1991-2004 | |
| Pakistan[a] | 1951, 1958, 1965, 1966, 1967, 1968 | 1975, 1976, 1979, 1987 | 1992, 1994, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004 | 0.36 |
| India[b] | 1950, 1951, 1952, 1958, 1963, 1964, 1965, 1966, 1967, 1968, 1969 | 1971, 1972, 1973, 1974, 1979, 1982, 1983, 1985, 1986, 1987, 1988 | 1993, 1996, 2000, 2002 | 0.46 |
| Nepal[c] | 1964, 1967 | 1973, 1974, 1977, 1979, 1980 | 1992, 1994, 2001, 2002, 2005 | 0.21 |
| Bangladesh[d] | 1950, 1951, 1957, 1959, 1963, 1965, 1969 | 1972, 1974, 1978, 1979, 1982, 1983, 1986, 1989 | 1992, 1994, 1995, 1997 | 0.34 |
| Myanmar[e] | 1954, 1957, 1960, 1963, 1966 | 1972, 1977, 1990, 1979 | 2002, 2004 | 0.20 |
| Sri Lanka[f] | 1953, 1956, 1961, 1966, 1967 | 1975, 1976, 1977, 1979, 1980, 1981, 1982, 1983, 1987, 1989 | 1996, 2001, 2002, 2003, 2004 | 0.36 |
| Thailand[g] | 1952, 1953, 1954, 1955, 1958, 1966, 1967, 1968 | 1972, 1974, 1976, 1977, 1978, 1979, 1986, 1987 | 1991, 1992, 1993, 1997, 1998, 1999, 2000, 2001, 2004 | 0.45 |
| Malaysia[h] | 1958, 1959, 1961, 1963 | 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1983, 1987 | 1991, 1997, 1998 | 0.29 |
| Indonesia[i] | 1953, 1961, 1962, 1963, 1965, 1966, 1967, 1969 | 1972, 1973, 1976, 1977, 1978, 1979, 1982, 1984, 1986, 1987, 1990 | 1991, 1993, 1994, 1997, 1998, 2003 | 0.46 |
| Vietnam[j] | 1957, 1963, 1966 | 1976, 1977, 1979, 1980, 1987 | 1993, 1994, 1995, 1997, 1998, 1999, 2002, 2004, 2005 | 0.30 |
| Cambodia[k] | 1954, 1955, 1958, 1963, 1968, 1970 | 1972, 1974, 1976, 1977, 1979, 1987 | 1994, 1996, 1997, 2001, 2002, 2003, 2004, 2005 | 0.34 |

*contunued on next page*

**Table 1.2. continued.**

| Country | Occurrence of drought during | | | Drought probability |
|---|---|---|---|---|
| | 1950-70 | 1971-90 | 1990-2004 | |
| Lao PDR[l] | 1954, 1967 | 1972, 1975, 1976, 1977, 1979, 1980, 1982, 1983, 1986, 1987, 1988, 1989 | 1991, 1992, 1993, 1994, 1996, 1998, 1999, 2002, 2004 | 0.42 |
| Philippines[m] | 1957, 1958, 1968, 1969 | 1972, 1973, 1976, 1977, 1978, 1982, 1983, 1987, 1989, 1990 | 1991, 1992, 1993, 1994, 1995, 1997, 1998, 2002, 2004 | 0.41 |
| China[n] | 1955, 1956, 1958, 1959, 1960, 1962, 1965, 1966 | 1971, 1972, 1978, 1979, 1982, 1983, 1985, 1986, 1988 | 1991, 1992, 1994, 1997, 1999, 2000, 2001, 2002, 2003, 2004 | 0.48 |

Note: Drought occurring in the whole country that is reported in at least one of the sources is listed as a drought year. Drought probability was obtained by dividing the number of drought years by the total number of years in the data.
Sources:
[a]Steyaert et al (1981), EM-DAT (2005), Ahmad et al (2004). [b]Steyaert et al (1981), EM-DAT (2005), The Fertilizer Association of India (2002), Nagarajan (2003), Samra (2004). [c]Steyaert et al (1981), EM-DAT (2005), MOPE Nepal (2002), IFRC (2002), IANS (2005). [d]Steyaert et al (1981), EM-DAT (2005), Paul (1995), Hossain et al (2000), Choudhury (2000). [e]Steyaert et al (1981), BurmaNet News (2002), USDA (2005). [f]Steyaert et al (1981), EM-DAT (2005), ADRC (2003a), FAO (2004). [g]Steyaert et al (1981), EM-DAT (2005), TDRI (1994), University of Southampton (2001), TFRC (1998, 1999, 2002), Suwanbatr and Mekhora (2002), Ministry of Interior (2005), KRC (2004). [h]Steyaert et al (1981), EM-DAT (2005), Shaaban and Sing (2003). [i]Steyaert et al (1981), EM-DAT (2005), Holmes (1998). [j]Steyaert et al (1981), EM-DAT (2005), UNDP/MARD (2002), Vietnam News Agency (2004, 2005), Oxfarm (2005). [k]Steyaert et al (1981), EM-DAT (2005), Reuters News Service (1994), UNOCHA (2002), Oxfarm (2005). [l]Steyaert et al (1981), EM-DAT (2005), Schiller et al (2001), ADRC (2003b, 2005). [m]Steyaert et al (1981), EM-DAT (2005), DENR (1999), USDA (2005). [n]EM-DAT (2005), Li and Lin (1993), China Daily (2004), Ding et al (2005), Zhang (1999), Jun and Chen (2001).

the analytical methods used for characterizing drought, estimating the aggregate and household-level impacts of drought, and examining farmers' drought-coping mechanisms. The results of the country-specific studies are presented in the three subsequent chapters. A synthesis of findings and implications for drought-mitigating interventions are presented in the final chapter.

## References


ADRC (Asian Disaster Reduction Center). 2003a. Sri Lanka: country report on natural disasters. Kobe (Japan): ADRC. Online at www.adrc.or.jp.

ADRC (Asian Disaster Reduction Center). 2003b. Lao PDR: country report on natural disasters. Kobe (Japan): ADRC. Online at www.adrc.or.jp.

ADRC (Asian Disaster Reduction Center). 2005. Natural disasters in Lao PDR (period, type) (1901-2000). Kobe (Japan): ADRC. Online at www.adrc.or.jp/publications/databook/databook_20th/LAO.pdf. Accessed in December 2005.

Ahmad S, Hussain Z, Tureshi AS, Majeed R, Saleem M. 2004. Drought mitigation in Pakistan: current status and future options. IWMI Working Paper 85. Colombo (Sri Lanka): International Water Management Institute.

Asia Times. 2005. Grim reaping for Thai farmers: a news report on Southeast Asia. Hong Kong (China): Asia Times Online Co., Ltd. Online at www.atimes.com. Accessed 29 April 2005.

Bank of Thailand. 2005. The inflation report. January 2005. Bangkok (Thailand): The Bank of Thailand. 97 p.

BBC News. 2005. Drought hits Thailand's economy: a business news report. London (UK): British Broadcasting Corporation (BBC). Online at http://news.bbc.co.uk/hi/business. Accessed 15 March 2005.

BurmaNet News. 2002. Infamous triangle is still tainted: a news report. Online at www.burmanet.org. Accessed 16 December 2005.

Campbell DJ. 1999. Response to drought among farmers and herders in Southern Kajiado district, Kenya: a comparison of 1972-1976 and 1994-96. Human Ecol. 27(3):377-416.

China Daily. 2004. Drought in South China causes great losses: a news report. The China Daily Newspaper. Online at www.chinadaily.com.cn. Accessed 12 November 2004.

Choudhury SQ. 2000. Banglapedia: drought. A news article. Asiatic Society of Bangladesh. Online at www.sd_0284.htm.

DENR (Department of Environment and Natural Resources). 1999. The Philippines' initial national communication on climate change. Manila (Philippines): DENR. Online at www.gov.ph. Accessed December 1999.

Ding S, Pandey S, Chen C, Bhandari H. 2005. Drought and rice farmers' coping mechanisms in the rice production systems of southern China. A final research report submitted to the Rockefeller Foundation. Department of Agricultural Economics, Huazhong Agricultural University. Hubei (China): Huazhong Agricultural University.

EM-DAT. 2005. EM-DAT: the OFDA/CRED international disaster database. Brussels (Belgium): Université Catholique de Louvain. Online at www.em-dat.net. Accessed in December 2005.

FAO (Food and Agriculture Organization of the United Nations). 2001. Report of the Asia-Pacific conference on early warning, prevention, and preparedness and management of disasters in floods and agriculture. Chiang Mai, Thailand, 12-15 June 2001. Bangkok (Thailand): FAO Regional Office for Asia and the Pacific (RAP) Publication No. 2001/14. Bangkok (Thailand): FAO/RAP.

FAO (Food and Agriculture Organization of the United Nations). 2004. Sri Lanka: special report. Update on drought conditions for 2003/04 Maha and 2004 Yala seasons. Economic and Social Department. Rome (Italy): FAO. Online at www.fao.org. Accessed on 10 December 2004.

Hazell P, Oram P, Chaherli N. 2001. Managing droughts in low-rainfall areas of Middle East and North Africa. Environment and Production Technology Division (EPTD) Discussion Paper 78. Washington, D.C. (USA): International Food Policy Research Institute.

Holmes D. 1998. Droughts in Java and Bali since 1950. The SMERU Research Institute Newsletter No. 1/November 1998. Jakarta (Indonesia). The SMERU Research Institute. Online at www.smeru.or.id/newslet/1998.

Hossain E, Alam SH, Imam KH, Hoque MM. 2000. Reducing the impact of environmental emergencies through early warning and preparedness: the case of El Niño Southern Oscillation (ENSO). In: Bangladesh case study: impacts and responses to 1997-98 El Niño events. A UNF/UNEP/NCAR/UNU/WMO/ISDR assessment. October 2000. New York (USA): United Nations. Online at www.unu.edu/env/govern/ElNino/CountryReports.

IANS (Indo-Asian News Service). 2005. Drought looms over Nepal. A news report 8 August 2005. Indo-Asian News Service India Pvt. Ltd., India. Online at www.ians.in.

IFRC (International Federation of Red Cross and Red Crescent Societies). 2002. South Asia struck by floods and drought: a news report. Geneva (Switzerland): IFRC.

Iran Daily. 2005. Asian drought affects millions. A news report on international economy. Tehran (Iran): Iran Daily. Online at www.iran-daily.com. Accessed 6 March 2005.

IRRI (International Rice Research Institute). 1997. Rice almanac. Second edition. Manila (Philippines): IRRI. 181 p.

Jodha NS. 1978. Effectiveness of farmers' adjustment to risk. Econ. Polit. Weekly 13(25): A38-A48.

Jun X, Chen YD. 2001. Water problems and opportunities in the hydrological sciences in China. Hydrol. Sci. 46(6):907-921.

KRC (Kasikorn Research Institute). 2004. Drought in 2004: advance preparedness: an executive summary on current issues. Bangkok (Thailand): The KRC.

Li K, Lin X. 1993. Drought in China: present impacts and future needs. In: Wilhite DA, editor. Drought assessment, management, and planning: theory and case studies. Dordrecht (The Netherlands): Kluwer Academic Publishers. p 263-289.

Mackill DJ, Coffman WR, Garrity DP. 1996. Rainfed lowland rice improvement. Manila (Philippines): International Rice Research Institute. 242 p.

Ministry of Interior. 2005. Disaster prevention and mitigation: the country report of Thailand 2005. Research and International Cooperation Bureau, Department of Disaster Prevention and Mitigation. Bangkok (Thailand): Ministry of Interior. Online at www.disaster.go.th.

MOPE (Ministry of Population and Environment of Nepal). 2002. Nepal: national action program on land degradation and desertification in the context of United Nations Convention on Combating Desertification (UNCCD). Kathmandu (Nepal): MOPE.

Nagarajan R. 2003. Drought: assessment, monitoring, management, and resources conservation. New Delhi (India): Capital Publishing Company. 312 p.

Oxfarm. 2005. Drought in Cambodia: waiting for the first rain. A situation report on Cambodia, June 2005. Oxford (UK): Oxfarm International. Online at www.oxfarm.org.uk.

Paul BK. 1995. Farmers' and public responses to the 1994-95 drought in Bangladesh: a quick response report 76. Department of Geography. Manhattan, Kansas (USA): Kansas State University.

Rathore JS. 2004. Drought and household coping strategies: a case of Rajasthan. Indian J. Agric. Econ. 59(4):689-708.

Reuters News Service. 1994. Drought-ravaged Cambodia seeks international help: a news report. Reuters News Service. 29 Nov. 1994. Available online at http://archive.greenpeace.org/climate.

Samra JS. 2004. Review and analysis of drought monitoring, declaration, and impact management in India. IWMI Working Paper Number 84-Drought Series Paper Number 2. Colombo (Sri Lanka): International Water Management Institute.

Schiller JM, Linquist B, Douangsila K, Inthapanya P, Boupha BD, Inthavong S, Sengxua P. 2001. Constraints to rice production systems in Laos. In: Fukai S, Basnayake J, editors. Increasing lowland rice production in Mekong region. Australian Center for International Agricultural Research (ACIAR) Proceedings No. 101. Canberra (Australia): ACIAR. Online at www.aciar.gov.au.

Shaaban AJB, Sing LK. 2003. Drought in Malaysia: a look at its characteristics, impacts, and related policies and management policies. A paper presented at the Water and Drainage Conference, 28-29 April 2003, Kuala Lumpur, Malaysia. Selangor (Malaysia): National Hydraulic Research Institute of Malaysia (NAHRIM), Ministry of Natural Resources and Environment. Online at www.nahrim.gov.my.

Shivakumar S, Kerbart E. 2004. Drought, sustenance and livelihoods: "Akal" survey in Rajasthan. Econ. Polit. Weekly 39(3):285-294.

Sinha A. 1999. Natural disaster management in India. A country report from member countries. Kobe (Japan): Asian Disaster Reduction Center. Online at www.adrc.or.jp.

Steyaert LT, Rao AV, Todorov AV. 1981. Agroclimatic assessment methods for drought/flood strategies in South and Southeast Asia. Washington, D.C. (USA): United States Agency for International Development.

Suwanabatr B, Mekhora T. 2002. Stabilization of upland agriculture under El Niño-induced climatic risk: impact assessment and mitigation measures in Thailand. CGPRT Center Working Paper no. 63.. Bogor (Indonesia): The Regional Co-ordination Center for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific. 46 p.

TDRI (Thailand Development and Research Institute). 1994. Thailand's drought crisis. TDRI Quarterly Review 9(1):28-29. Bangkok (Thailand): TDRI.

The Fertilizer Association of India. 2002. Fertilizer statistics 2001-02. New Delhi (India): The Fertilizer Association of India.

TFRC (Thai Farmers Research Bank Company). 1998. Warning of drought: an executive summary on current issues. Bangkok (Thailand): Thai Farmers Research Bank Co. Ltd.

TFRC (Thai Farmers Research Bank Company). 1999. The drought crisis: another problem for agriculture in 1999. An executive summary on current issues. Bangkok (Thailand): Thai Farmers Research Bank Co. Ltd.

TFRC (Thai Farmers Research Bank Company). 2002. Drought crisis: impacts on 2002's agricultural outputs. An executive summary on current issues. Bangkok (Thailand): Thai Farmers Research Bank Co. Ltd.

UNDP/MARD 2002. Summing-up report on disaster situations in recent years and preparedness and mitigation measures in Vietnam. The UNDP/MARD Disaster Management Unit, Vietnam, VIE/97/2002. Hanoi (Vietnam): The United Nations.

University of Southampton. 2001. Effect of climate and land use change on river hydrology of Thailand, revealed using statistical analysis of meteorological and river-discharge time-series data. A LINK project report. Cambridge (UK): Department of Geography, University of Southampton. Online at www.geog.soton.ac.uk/research/thaihyd. Accessed in July 2005.

UNOCHA (United Nations Office for the Coordination of Humanitarian Affairs). 2002. Cambodia-Drought OCHA situation report no. 3. UNOCHA situation report no. 3, 26 Dec 2002. New York, NY (USA): The United Nations. Online at www.reliefweb.int.

USDA (United States Department of Agriculture). 2005. Drought continues in Southeast Asia: a crop production assessment report. Production Estimates and Crop Assessment Division, Foreign Agricultural Service. Washington, D.C. (USA): USDA. Online at www.fas.usda.gov. Accessed 24 March 2005.
Vietnam News Agency. 2004. Severe drought persists throughout Vietnam: a news report. Viet Nam News: The National English Language Daily. 23 December 2004. Hanoi (Vietnam): Vietnam News Agency. Online at http://vietnamnews.vnagency.com.vn.
Vietnam News Agency. 2005. Ministry seeks emergency aid to mitigate drought. Viet Nam News: The National English Language Daily. 30 December 2005. Hanoi (Vietnam): Vietnam News Agency. Online at http://vietnamnews.vnagency.com.vn.
Zhang GL, editor. 1999. Water supply and demand in China in the 21st century. Beijing (China): Chinese Water Resources and Hydropower Press. (In Chinese.)

## Notes

*Authors' addresses:* S. Pandey, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines; H. Bhandari, Social Sciences Division, International Rice Research Institute, currently with Japan International Research Center for Agricultural Sciences, 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan.

CHAPTER 2

# Drought: an overview

S. Pandey and H. Bhandari

This chapter provides an overview of the conceptual and analytical approaches for measuring the economic impact of drought. Both farm-level and national-level impact are considered. The discussion is based mainly on the context of rice farming in Asia.

## 1. Drought: a definition

Drought is a recurring climatic event and a global phenomenon but its features vary from region to region. It is a chronic problem in arid and semiarid regions and it frequently occurs in humid regions as well. The common belief that drought occurs only in low-rainfall areas is not true indeed. The repeated occurrence of drought in the Indian state of Orissa, having an average annual rainfall of 1,300 mm, is an example.

Conceptually, drought is considered to describe a situation of limited rainfall that is substantially below what has been established to be a "normal" value for the area concerned, leading to adverse consequences on human welfare. Although drought is a climatically induced phenomenon, its impact depends on social and economic contexts as well. Hence, in addition to climate, economic and social parameters should be taken into account when defining drought. Considering its complex nature and wide variation across time and space, it is somewhat impractical to develop a universally applicable definition of drought. Also, the definition depends on the disciplinary perspective. Three such definitions, based on meteorological, hydrological, and agricultural perspectives, are available (Wilhite and Glantz 1985).

Meteorological drought is defined as a situation in which actual rainfall is significantly below the long-term average (LTA) for the area. This definition does not take into account factors other than rainfall. Hydrological drought is defined as the situation of depletion in surface and subsurface water resources due to a shortfall in precipitation. The effect on depletion of water resources is the main concern in this definition.

Agricultural drought is said to occur when soil moisture is insufficient to meet crop water requirements, resulting in yield losses. It is thus closely linked to soil moisture deficit leading to acute moisture stress and production loss. As the effect of rainfall deficiency on the crop also depends on soil and crop characteristics, the definition of agricultural drought requires consideration of actual and potential evapotranspiration, soil water deficit, and production losses simultaneously.

All these definitions of drought are interrelated in terms of impact, and agricultural and hydrological droughts are almost inevitable when meteorological drought occurs. Despite the varying disciplinary perspectives, all these definitions consider the following set of closely linked factors: (1) primary interest in precipitation (meteorologist), stream flow (hydrologist), and soil moisture (agriculturist), and (2) region-specific characteristics of drought. The effect of drought on agriculture and society is the main interest of this study.

When drought occurs, the agricultural sector is usually the first to be affected. Even though the meteorological drought is over, the adverse economic impact of drought may persist for several years depending upon the nature of drought. The affected farmers may deplete their productive assets, borrow heavily to meet their consumption needs, and undergo other adjustments that prevent them from bouncing back smoothly to their original level of production capacity when the drought is over. In addition, land degradation in the form of overexploitation of forests, pastures, and water resources may occur, resulting in a lower future production capacity. Such adjustments, if widespread, may adversely affect even the overall long-run agricultural potential of the ecosystem.

Crop response to moisture deficit also depends on the timing and intensity of drought. Most annual crops are highly sensitive to moisture deficits during flowering and grain formation. Even short periods of drought during these critical stages of crop growth can cause substantial production loss. In the case of rice, early-season drought (during the planting stage) normally leads to a reduction in area planted as dry conditions prevent farmers from successfully establishing the crop.

In addition to the timing and intensity, the aggregate impact of drought also depends on the spatial covariance. A widespread drought covering a large area (i.e., spatially covariate drought) will have a much larger impact than a localized drought. The 2002 drought in India, for example, was widespread and affected more than half of the country's geographical area.

## 2. Economic costs of drought

Drought is a unique natural disaster that differs from other natural disasters in three main aspects (Wilhite 2000). First, drought is a "creeping phenomenon," making its onset and end difficult to determine. Its effects accumulate slowly over a considerable period of time, and may linger for years even after the termination of the event. Second, the absence of a precise and common definition of drought adds to the confusion about its occurrence and severity. Third, its impact does not normally involve damage to infrastructure (unlike flood, earthquake, etc.). Because of the less obvious damage, drought receives much less attention from media, policymakers, and politicians than it warrants. Drought produces a complex set of highly differentiated adverse impacts that ripple through many sectors of the economy. It affects the biophysical, socioeconomic, and environmental sectors of the region hit. Some of these consequences are long-term and irreversible.

The multifaceted impact of drought can be categorized as physical, economic, social, and environmental. The large magnitude of losses in agriculture makes drought a major source of risk, uncertainty, and hardship for farm households, especially the poor. It has been argued that the costs and impact of drought are increasing in recent times, not because the frequency and/or severity of drought increases; rather, the vulnerability of society to drought is increasing due to growing population, changing farming practices, and increased competition for water (Wilhite 1993, Alston and Kent 2004, UNDP 2004, ODI 2005).

About 38% of the world's area that nearly 70% of the total population inhabits and that contributes 70% of agricultural output worldwide is exposed to drought (Dilley et al 2005). Drought has been associated with food insecurity, malnutrition, starvation, poverty, disinvestment in human capital, and draining of fiscal resources. Table 2.1 presents a summary of some of the far-reaching consequences of drought. In Africa, the livelihood of millions of people is shattered by recurring drought. The countries in the region are forced to allocate a huge amount of financial resources for emergency relief, which takes resources away from development programs. Asia is no exception in terms of suffering from drought.

## 3. Farmers' drought-coping mechanisms

In risk management literature, a distinction is often made between adaptive strategies that reduce risk and others that are used to deal with the losses that do occur (Davies 1996). The term "coping" is used in this conceptualization to refer to the latter set of strategies only. As argued by Dercon (2002), these two sets of strategies are related, not independent. Hence, a broader definition of coping to include both these strategies is used here.

Risk-coping strategies can be classified into ex ante and ex post depending upon whether they help to reduce risk or reduce the impact of risk after a production shortfall has occurred. Due to a lack of efficient market-based mechanisms for diffusing risk, farmers modify their production practices to provide "self-insurance" so that the likely impact of adverse consequences is reduced to an acceptable level. Ex ante strategies help reduce fluctuations in income and are also referred to as income-smoothing strategies. These strategies can, however, be costly in terms of forgone opportunities for income gains as farmers select safer but low-return activities.

Ex ante strategies can be grouped into two categories: those that reduce risk by diversification and those that do so by imparting greater flexibility in decision making. Diversification is simply captured in the principle of not putting "all eggs in one basket." The risk of income shortfall is reduced by growing several crops that have negatively or weakly correlated returns. This principle is used in different types of diversification common in rural societies. Examples are spatial diversification of farms, diversification of agricultural enterprises, and diversification from farm to nonfarm activities.

**Table 2.1. Impact of important drought events in recent years.**

| Drought years | Affected country | Impact of drought |
|---|---|---|
| 1980-84[a] | Horn of Africa | About 40 million people affected in the Horn of Africa. |
| 1980-85[b] | Africa | Around 150 million people in Africa affected. |
| 1983-84[c] | USA, Europe, and Africa | World grain production declined by 5% vis-à-vis the previous year. |
| 1991-92[d] | Africa | Maize production declined by 60% and caused import of 5 million tons of maize in the following year. |
| 2002[e] | Sub-Saharan Africa | Over 40 million people faced food crisis. |
| 2004[f] | Africa | Famine, malnutrition, and death from hunger in many parts of Africa. |
| 2004[g] | China | Drought affected 23 million people in 52% of the provinces, affected crop area of 16 million ha, and loss was estimated to be 1.3% of agricultural sector GDP. |
| Annual[h] | China | Annual loss due to drought is estimated to be 0.5–3.3% of agricultural sector GDP. |
| 1957-58[i] | India | Agricultural production loss due to drought was 50% vis-à-vis the previous year. |
| 1987[i] | India | Affected 60% of the crop area and 285 million people. |
| 2002[j] | India | Affected 55% of the country's area and 300 million people. Food grain and rice production declined by 15% and 19% from trend values, respectively. |
| 1998[k] | Thailand | Affected 95% of the provinces, affected crop area of 0.9 million ha, and loss estimated to be 2.4% of agricultural sector GDP. |
| 2004[k] | Thailand | Affected over 8 million people in 92% of the provinces, affected crop area of over 2 million ha, and production loss estimated to be 2.2% of agricultural sector GDP. |
| 2004[f] | Vietnam | Affected about 1 million people in eight highland provinces and agricultural production loss is estimated to be $80 million. |
| Annual[l] | USA | Annual loss due to drought is estimated to be $6–8 billion. |

Sources:
[a]AMS (1997). [b]Loftas and Ross (1995). [c]Wisner and Chase (1984). [d]Kumar (2005). [e]FAO (2002). [f]Reuters (2005). [g]MWR (2004). [h]Chapter 6 of this publication (China). [i]FAO (2001). [j]PACS (2004). [k]Bank of Thailand (2005). [l]ISDR-UN (2005).

Maintaining flexibility is an adaptive strategy that allows farmers to switch between activities as the situation demands. Flexibility in decision making permits farmers not only to reduce the chances of low income but also to capture income-increasing opportunities when they do arise. Examples are using split doses of fertilizer, temporally adjusting input use to crop conditions, and adjusting the area allocated to a crop depending on climatic conditions. While postponing agricultural decisions until uncertainties are reduced can help lower potential losses, such a strategy can also be costly in terms of income forgone if operations are delayed beyond the optimal biological window.

Ex post strategies are designed to prevent a shortfall in consumption when income drops below what is necessary for maintaining consumption at its normal level. Ex post strategies are also referred to as consumption-smoothing strategies as they help reduce fluctuations in consumption even when income is fluctuating. These include migration, consumption loans, asset liquidation, and charity. A consumption shortfall can occur despite these ex post strategies if the drop in income is substantial.

Farmers who are exposed to risk use these strategies in different combinations to ensure their survival despite all odds. Over a long period of time, some of these strategies are incorporated into the nature of the farming system and are often not easily identifiable as risk-coping mechanisms. Others are employed only under certain risky situations and are easier to identify as responses to risk.

## 3.1 Ex ante coping mechanisms (income smoothing)

Ex ante coping mechanisms are designed to exploit the low correlation among activity returns for stabilization of total income. These operate through various types of diversification that characterize traditional agriculture. Diversification can be considered as being horizontal or vertical. The former refers to scattering agricultural fields, growing several crops, growing several varieties of the same crop, and being engaged in different income-generating activities. Vertical diversification relates to spreading agricultural operations over time. This refers to strategies such as staggered planting, spreading input use over a period of time, and planting many seeds per hill. Vertical diversification is a way of maintaining flexibility to adjust agricultural operations to the evolving uncertainty. Similarly, sharecropping is viewed as a way of reducing risk through sharing of risk between the landlord and the tenant.

*Spatial diversification of fields.* Agricultural fields vary from location to location in attributes such as soil moisture retention and fertility. In rainfed areas, soil property can vary widely even from paddock to paddock. Similarly, distribution of rainfall can also vary among fields in different locations. These variations in soil property and rainfall across locations create an opportunity for farmers to stabilize their agricultural output through spatial scattering of fields. Although output from fields situated in one location may decrease because of poor rainfall, it may increase in fields in other locations that receive higher rainfall. Weakly or negatively correlated crop yields across fields result in these compensating movements so that the total farm output is more stable than the output from individual fields. Spatial scattering of fields is a way of exploiting this stabilizing effect. In addition, this strategy may also help farmers to better exploit the specific niches of different microenvironments for productivity enhancement. In spite of these potential gains, spatial diversification of fields can cause an efficiency loss due to the increased costs of moving inputs across and marketing outputs from widely separated fields. Whether or not farmers use spatial scattering depends on the net effect of these factors. In addition, institutional setup such as the inheritance law may condition the prevalence of such a practice.

In the rice-growing regions of Asia, it is not uncommon to find a farm household operating several parcels of land that are either spatially scattered or, even in one location, that differ in their position along the toposequence. Although risk considerations may have played a role in determining the extent of land fragmentation, casual observation indicates that land fragmentation is driven mainly by the desire to exploit different environmental niches that are suitable for different crops. In parts of eastern India, all parcels of land are divided among legal heirs so that everybody gets an equal share of all types of environmental niches. The desire for an equitable distribution of land of different quality among heirs is often considered to be a factor constraining efforts at land consolidation.

If land fragmentation is an effective way of reducing risk, one would expect to observe a greater degree of fragmentation in areas where environmental conditions are less stable. However, such a pattern may not be observed because of other counteracting factors. For example, the extent of fragmentation in the more risky Sahel region of Africa has been found to be less than in the more favorable Sudan region (Matlon 1991). This is attributed to the differences in the environmental factors in these two regions. In the Sahel, low rainfall prevents farmers from cultivating a wider range of field types. As a result, cropping is restricted to only certain field types where crop success is more assured. In the case of the Sudan zone, higher rainfall and generally better soil conditions enable farmers to use a range of field types. In this example, the lack of feasible alternatives in a highly constraining environment of the Sahel reduced the value of spatial diversification as a risk management tool.

*Crop diversification.* As with spatial diversification, growing several crops with poorly or negatively correlated yields can stabilize farm output. Environmental conditions less favorable to some crops may be more favorable to others so that compensating variations in yields of different crops would impart stability to total output. In addition to risk reduction, crop diversification has several other potential benefits. These other considerations are a better exploitation of environmental niches, staggering of labor demand, and meeting the demand for a range of outputs. Mixed cropping and intercropping, which are a common feature of traditional agriculture in Asia, are a form of crop diversification that reduces output variability (Walker and Jodha 1986, Siddiq and Kundu 1993, Bardhan and Udry 1999, Rathore 2004). Farmers also practice relay cropping and crop substitution to reduce output variability (Lazo and Tapay 1999). Crop diversification, however, can also be costly in terms of income gain forgone as farm households include crops with lower but more stable yields in their cropping pattern. In addition, economies of size that may result from specialization are also lost as production is diversified.

Crop diversification is a feature of traditional farming systems in Asia. The role of crop diversification in risk reduction has been analyzed extensively in the context of farming in the semiarid tropics, where farmers grow a range of intercrops and mixed crops. The extent of crop diversification has been found to be greater in the more risky environments in the semiarid tropics of India (Walker and Jodha 1986). In the rainfed rice environments of eastern India, the extent of crop diversification is greater in areas with less assured supply of irrigation (Pandey et al 1998). It has also been found that the extent of crop diversification in flood-prone areas in a village in eastern India declined after dikes for flood protection were constructed (Ballabh and Pandey 1999).

Although diversification may reduce instability, whether or not farmers are able to diversify land use also depends on environmental conditions. Again taking an example from Africa, low and unstable rainfall and poor soils in the Sahel have constrained opportunities for diversification, with the millet-based cropping pattern being the dominant one. In comparison, in the relatively favorable environments of the Northern Guinea zone, the cropping pattern is more diversified (Matlon 1991). In addition, the more limited cropping opportunities in the Sahel also mean that crop yields are likely to be highly correlated, thus reducing the benefits from crop diversification. In the humid environments of Asia, drainage constraints in submergence-prone bottomland similarly limit opportunities for crop diversification during the rainy season.

*Varietal diversification.* Growing several varieties of a crop is a form of diversification that can stabilize total crop output if yields of different varieties are poorly correlated. Varieties with different duration can reduce risk by avoiding period-specific risk. For example, short-duration varieties can escape terminal drought that can affect the yield of a longer-duration variety severely. Similarly, varieties with different degrees of tolerance for pests and diseases also help reduce losses.

Rainfed rice farmers in eastern India almost invariably grow several varieties for different reasons, including possible risk reduction. In a rainfed rice village in Orissa, more than 70% of the farmers have been found to grow two to five varieties with 20% of the farmers growing six to eight varieties (Kshirsagar et al 1997). Similarly, in the rainfed lowland of Laos, 60% of the farmers grow four or more rice varieties (Pandey and Sanamongkhoun 1998). As with crop diversification, other advantages of varietal diversification are niche matching, staggering labor demand, and generating a range of product characteristics. These latter motives are not directly related to risk management and may condition the extent of varietal diversification practiced by farmers in a given area.

*Income diversification.* Like crop diversification that uses weak correlation among activity returns to stabilize farm income, diversification of income from farm to nonfarm sources is another way of stabilizing income (Bardhan and Udry 1999, Lazo and Tapay 1999, Kuhl 2002, Skoufia 2003). If fluctuations in nonfarm income are independent of fluctuations in farm output, income diversification through one or more members of the family working in the nonfarm sector can stabilize total family income. The extent of income diversification may be dependent on factors such as rural education, transportation infrastructure, access to institutional credit, and availability of local resources for nonfarm activities. These factors may constrain the opportunities for income diversification even when agricultural risk is high. Some of these entry barriers may lead to different types of income diversification among income classes. For example, the poor typically enter into activities with low entry costs such as working as wage earners (Dercon 2002). In addition, income diversification may not result in income stabilization if farm and nonfarm incomes are covariate. This tends to happen, for example, in drought years, when income from both farm and nonfarm sectors tends to be adversely affected (Dercon 2002).

The nature of income diversification also depends on several factors. In areas with environmental conditions conducive to a strong agricultural base, income-generating activities that take advantage of agriculture's forward and backward linkages expand. On the other hand, income diversification in agriculturally poor areas tends to be outward looking, with households diversifying their income geographically (Reardon et al 1988, 1992, Barrett et al 2001).

*Sharecropping.* A large volume of literature on risk and efficiency implications of sharecropping exists (Newbery and Stiglitz 1979, Otsuka et al 1992). At its very basic, sharecropping arrangements that lead to sharing of input and output also lead to sharing of risk between the landlord and tenant. However, the existence of sharecropping is dependent on many other factors and potential risk-sharing benefits may not be the principal reason for sharecropping (Otsuka et al 1992).

*Temporal adjustments (vertical diversification).* Crop growth is a biological process that occurs over a period of time. The economic output is obtained upon maturity when the crop is finally harvested. The crop is exposed to various factors during the intervening period between planting and harvest. Some of these factors are known with a fair degree of certainty whereas others are highly uncertain. These factors, together with management interventions by farmers, determine the ultimate economic value of the crop output. Uncertainties are highest at planting time as future values of uncertain events are known very imprecisely. As uncertainties are resolved with the passage of time, farmers can gain by making decisions conditional on the realization of uncertain events up to that time and on the revised expectation about the future realization of uncertain events. Such a sequential decision-making process imparts flexibility and allows farmers to exploit favorable events for income gains while reducing potential losses.

To assess the value of sequential decision making, it may be useful to divide the cropping season into early, mid, and late stages. The early stage can be considered to include preplanting and the period immediately after planting. The major decisions to be made at this stage are the crop, variety, timing of planting, and method of establishment. The mid-stage is considered to be the period between successful crop establishment and flowering. Major decisions here are weeding, fertilization, control of pests, and irrigation. The final stage involves the period after flowering until harvest.

The rainfall pattern during the early stages may determine the choice of crops. If rains are low or delayed during this period, farmers may forego rice completely and expand the area under crops that require less water. Similarly, if too much water is received, farmers may expand the area under rice at the expense of other crops. In eastern India, sown area of rice has been found to contract in years with low and unstable early-season rainfall (Pandey et al 1998). If the crop fails to establish itself due to too much or too little rain, farmers may decide to replant. Farmers similarly may engage in gap filling and thinning to reduce risk (Singh et al 1995).

The choice of what rice variety to grow also depends partly on the nature of rainfall during this early period. Farm-level data from eastern India indicate that, in years with late rains, farmers expand the area under short-duration varieties as a mechanism for escaping terminal drought. Expanding the proportionate area under traditional varieties and resorting more to dry seeding as opposed to transplanting are other responses exhibited by farmers in eastern India.

Once the crop is successfully established, farmers may adapt the level of input they use depending on their assessment of crop health. If the crop potential appears to be low, farmers may leave some fields unweeded and apply lower than normal quantities of fertilizer. Surplus resources may be used for other crops in the same or the following season. Farmers have even been found to replant the area with some other crops if they anticipate the rice yield to be too low and if the season has not advanced too far (Singh et al 1995).

During the third stage, most of the uncertainties would have been resolved and very few decisions would remain to be made. If rice fails during this stage, farmers may go for "salvage" operations to obtain at least the by-product (straw in the case of rice). Another response observed in eastern India is to establish post-rainy-season crops early in the rice field if soil moisture conditions are favorable.

The temporal adjustments described above are farmers' mechanisms for reducing losses in poorer years and increasing gains in more favorable years. Relative to committing all resources at the beginning of the cropping season or on the basis of a fixed calendar, average farm income will always be higher when flexible methods are adopted. However, opportunities for using flexibility may be constrained by farmers' ability to acquire and process the necessary information about crop status and the likely future realizations of uncertain events. In addition, in poorer and harsher environments, flexibility may be so circumscribed that it cannot be relied upon as an effective risk-coping mechanism.

*Crop insurance.* Like with other kinds of insurance, protection from crop failure could be obtained through crop insurance. It represents a financial means of risk-spreading mechanisms through which the costs of natural disasters are distributed among other sectors and throughout society. Crop insurance is normally provided or supported by the public sector in both developed and developing countries. The driving force for such a program often originates from public-sector concerns about catastrophic risk such as drought (Mishra 1996, Anderson 2001, Glauber and Collins 2002). Crop insurance is a contingency contract between the insurer and farmers in which farmers pay a premium to the insurer and receive indemnities under adverse conditions as specified in the contract. It is the most direct public policy response to address the problem of production risk and it provides a safety net for farmers.

Traditional crop insurance schemes, however, have largely failed worldwide. This is partially due to the high cost of monitoring, adverse selection, and moral hazards (Skees et al 2001, Varangis 2002, Bourgeon and Chambers 2003, Glauber 2004). Obtaining reliable data on individual yield by insurers is a major problem with conventional crop insurance schemes (Skees et al 1997, Ramaswami and Roe 2004). Other forms of crop insurance schemes have been proposed to overcome some of the difficulties with the conventional schemes.

Under their area-yield insurance scheme, producers receive indemnity payments based on a shortfall in aggregate area (such as county) yield rather than their individual yields. Similarly, the concept of weather index-based crop insurance has been introduced recently (Skees et al 1999, Mahul 2001, Turvey 2001, Varangis 2002, WB 2003, Glauber 2004). Weather insurance is based on the occurrence of weather events rather than on actual crop losses. Farmers would purchase a weather-based contract and be compensated when a natural disaster occurs.

Despite their significant benefits, there are important challenges in employing weather risk markets in developing countries (Varangis 2002, Skees et al 2001). Long-term reliable and verifiable meteorological data are needed to develop a weather index-based insurance product. This requires strong government support and investment in weather infrastructure in order to ensure accurate and tamper-proof measurements. Moreover, the effectiveness of the area-yield or weather index insurance contracts in reducing crop risk is largely related to how well the insured yield is correlated with the index (Glauber 2004).

Overall, crop insurance is a potentially useful instrument to protect farmers from weather-related risks. However, efforts to provide adequate protection to millions of subsistence-oriented rice farmers through crop insurance schemes have largely remained unsuccessful.

*Use of savings.* Farm households use savings kept in various forms as a risk-coping strategy. Savings can be viewed as an individual ex ante approach to smooth consumption as transitory income is put aside to be used in times of future need. Cash saving is an important consumption-smoothing strategy of households facing low and uncertain income. Paxson (1992) estimated the propensities to save out of transitory income due to rainfall shocks in the range of 0.73 to 0.83. In addition to cash and deposits, savings are also practiced in the form of grain stock and investment in assets such as jewelry, livestock, and land (Fafchamps et al 1998, Hoogeveen 2003). The saving in terms of food grains, although costly, provides a safety net during a crisis such as drought. The household behavior of saving in terms of food grain also reflects the seasonality of agriculture as well as market imperfections with high transaction costs for selling and buying their produce. Nevertheless, if saving is done in forms such as livestock or land, the investment will yield some returns while simultaneously acting as a safety net. Additionally, savings also have a positive externality on an economy, such as providing capital for investment in new technology and innovation. Thus, the availability of a good market for assets during a crisis period could encourage households to save in a normal year and minimize suffering during a crisis.

### 3.2 Ex post coping mechanisms (consumption smoothing)

How do farmers cope with losses that do occur despite the various risk-reducing mechanisms adopted? A shortfall in agricultural production will reduce consumption if farmers are not able to meet the deficit through some other means. Depleting food and cash savings, earning more wage income, borrowing, liquidating assets, reducing consumption, relying on charity, and permanent migration are some of the mechanisms used to cope with a production shortfall. The economic burden and long-term productivity impacts of these mechanisms differ.

If farmers are able to save during better-than-normal years and use these savings to meet consumption deficits during drought years, they may be able to maintain their consumption level over time despite short-term fluctuations in agricultural output (Rosenzweig 2001, Townsend 1995, Udry 1995, Kuhl 2002). The use of transitory income as savings can be an effective way to prevent future income shortfalls. Savings in agricultural societies can take various forms. They could be held in the form of food grains, cash, and jewelry. They could also be held in the form of productive assets such as bullocks, farm implements, and land. Empirical evidence from India indicates that real estate (land and buildings) accounts for approximately 85% of the total wealth of farm households. Of the non-real-estate wealth, bullocks account for the greatest share (27–50% depending on farm size) and jewelry accounts for approximately 19% (Rosenzweig and Wolpin 1993). Even if own savings are not enough to meet the consumption deficit, village-level institutions may permit sharing of risk across individuals such that individual consumption fluctuates much less than individual production.

Empirical evidence from several studies in developing countries indicates that consumption smoothing is a common practice among farmers (Paxson 1992, Rosenzweig and Wolpin 1993, Townsend 1994, 1995, Kochar 1999, WB 2000, Morduch 2001, 2005, Kuhl 2002, Harrower and Hoddinott 2004, Kazianga and Udry 2004). Based on data from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), crop inventory and cash reserves have been found to play major roles in smoothing consumption in the semiarid tropics of India (Lim and Townsend 1994, Paxson and Chaudhury 1993). The importance of these two mechanisms was found to vary by farm size, with large farmers relying more on crop inventory and small farmers relying more on currency.

The effectiveness of these mechanisms depends on the severity of drought and crop output in the preceding year. Problems are less severe in a year with mild drought that follows a good year and these mechanisms may be adequate to meet the shortfall. These internal reserves, however, may be grossly inadequate when drought years are consecutive or if the drought is severe. In such situations, farmers may be forced to reduce consumption.

Based on farm-level data from arid and semiarid areas of India, the decline in cereal consumption in a drought year relative to a normal year was found to vary from 12% to 22% (Jodha 1978). In addition, there were drastic cuts in expenditures on protective food such as milk, sugar, vegetables, fruits, meat, and others. Small and marginal farmers often postpone medical treatment and minor operations during drought years for monetary reasons (Umamaheswari and Khader 2004). Such shortfalls in consumption point to the inadequacy of consumption-smoothing mechanisms, especially among small farmers (Qureshi and Mujeeb 2004, Rathore 2004).

Livestock, in addition to being useful for agricultural production, are also an important store of wealth as well as source of income, employment, and nutrition in rural society. They serve an important role in consumption smoothing. During drought years, livestock are sold and the proceeds are used to overcome a consumption shortfall. Using the ICRISAT data from India, Rosenzweig and Wolpin (1993) showed that sales of bullocks increase significantly during drought years and purchases of bullocks increase during good years when income is above average. Disposal of livestock can also help reduce carrying costs, which tend to be high, especially during drought years (Kinsey et al 1998, Qureshi and Mujeeb 2004). In the Sahel zone of Africa, where poor environmental conditions constrain the efficacy of ex ante mechanisms, manipulation of livestock inventory is an important ex post mechanism (Matlon 1991, Sweet 1998, Katherine et al 1998). Farmers in India similarly use the livestock inventory to reduce consumption shortfall (Jodha 1978, Rathore 2004). In the Middle East and North Africa, mobile grazing, reciprocal grazing arrangements with distant communities, adjustment of flock sizes and stocking rates, and keeping extra animals that can be easily liquidated during drought are common drought-coping mechanisms (Hazell et al 2001).

A problem with the use of livestock for consumption smoothing is that this coping mechanism, while helping farmers to survive during drought years, can reduce long-term production potential. Where livestock are simply a store of wealth, this will not create a problem. Disposing of livestock in this case would be similar to withdrawing cash from the bank. In fact, disposal of small animals such as goats and sheep, which tend to be good stores of value, is generally the initial response to income shortfalls. However, livestock are also the major source of draft power needed for farm operations such as tillage, pumping irrigation water, threshing rice, and hauling farm inputs and outputs. Faced with the prospect of a severe shortage in consumption in a severe or prolonged drought, farmers may sell productive livestock such as cattle, buffaloes, and horses.[1] Once these productive livestock assets are depleted, it takes a long time for them to be replenished. Thus, even after the drought is over and rainfall returns to normal, it may take several years for farmers to build their stock of livestock.

A typical feature of the livestock depletion-replenishment cycle is that livestock are sold when their prices are falling due to excess supply during drought years (Jodha 1978). Increased demand during the replenishment phase pushes prices up, making it more difficult for farmers to reacquire the livestock. If a number of drought years occur in a row, the livestock asset may be depleted so severely that several years of normal conditions would be needed for full replenishment. The effect of drought can thus linger for several years until productive assets are fully replaced. As the mortality of livestock is higher in drought years due to poor nutrition, the asset base can deplete dramatically during a run of drought years. Thus, this coping mechanism could be costly in terms of future production potential forgone. The impact is likely to be greater for small farmers than for large farmers as small farmers often need a longer time to replenish the depleted stock.

Severe droughts can lead to excessive exploitation of common property resources (CPR) that are a critical component of village livelihood systems (Jodha 1986). The

---

[1]In some cases, farmers may opt to reduce consumption to protect their livestock herd, as indicated by Blench and Marriage (1999) in Africa.

CPR are resources owned in common by village residents. These include community forests, pasture/wasteland, ponds, river banks and riverbeds, and groundwater. The poorer segments of the rural population are especially dependent on CPR even in normal times to generate food, fiber, and income. During drought periods, these resources become even more important. For example, the reduced supply of fodder during drought years increases the reliance on forest and community grazing areas for sustaining the livestock. Similarly, additional income is generated by selling timber, fuel wood, and other forest products. The collection of edible forest products such as fruits, nuts, and bamboo shoots also increases as farmers attempt to meet a shortfall in production. If these CPR are depleted excessively during drought years, the productivity of agriculture and livelihood of the poor can be adversely affected for many years even after the meteorological drought is over.

Short-term or permanent migration to earn income from cities or faraway places is another coping mechanism (Findley 1994, Lazo and Tapay 1999, Shah 2001, Kuhl 2002, Shah and Shah 2005). Migration to nearby places is likely to be less effective because of covariate movements in income within a small geographic area. Prospects for earning income within the locality affected by drought are limited due to a reduction in demand for labor in agricultural as well as nonagricultural sectors. Employment in faraway places or in sectors unlikely to be affected by drought will have a stabilizing effect as such income is less covariate with income in drought-affected areas. In addition to seasonal migration during drought periods, diversification of earning with some family members working permanently in cities helps smooth consumption. A variant of this coping mechanism is having children get married to someone in another distant place. Income transfers through this mechanism have helped farmers in the semiarid tropics of India to stabilize consumption during drought years (Rosenzweig and Stark 1989, Rathore 2004). Similarly, diversification of income from the farm to nonfarm sector is a way of exploiting the low covariance for income and consumption stabilization. For example, the proportion of income derived from nonfarm employment outside the region has been found to be higher in the riskier Sahel zone than in the less risky Sudan zone of Africa (Matlon 1991).

Credit can potentially play an important role in smoothing consumption. Credit permits borrowing against future income potential to meet a current consumption shortfall. In a perfectly competitive market, the opportunity cost of credit is equal to the interest on savings. Hence, the long-run consumption will not depend on whether savings are used or credit is taken to meet the shortfall in consumption in poor years. In reality, credit markets are imperfect, with the effective interest rate on credit being higher than the interest on savings. Risk aversion among lenders, the high transaction cost of serving a large number of small farmers, and information asymmetry between borrowers and lenders are the major reasons for capital market failure in developing countries (Binswanger and Rosenzweig 1986). As a result, the use of credit for consumption smoothing in developing countries is limited, more so among small farmers, who are considered as high-risk borrowers by formal credit institutions.

Despite a poorly developed formal market for credit, the available evidence on the extent of consumption smoothing indicates the presence of informal institutional arrangements for risk sharing in rural areas. These may be village-level rice banks, local moneylenders, a mutual self-help group, interlocked credit and labor markets, and social and family networks. Income transfers (in cash or kind) through these informal arrangements can provide very effective insurance against idiosyncratic risks (Jodha 1978, Ben-Porath 1980, Platteau 1991, Fafchamps 1992, Townsend 1995, Kuhl 2002). The provision of such insurance is believed to be one of the critical functions of the family as an institution (Rosenzweig 1988).

Reducing large expenditures is another strategy of consumption smoothing of poor households. Low-income households attempt to minimize expenditures on health care, children's education, social functions, and purchase of new clothing when they experience a temporary decline in income. Using the 1998 financial crisis in Indonesia, Thomas et al (2004) showed that poor households reduce spending on children's education when they experience a major shortfall in income. Reducing consumption on protein-rich and vitamin-rich food items as well as postponing medical treatment are health-related adjustment strategies during economic crises (Umamaheswari and Khader 2004, Shah and Shah 2005).

Townsend (1994) demonstrated that local communities can and do mutually insure themselves against idiosyncratic income fluctuation. Various institutions such as the village grain bank, village seed bank, micro-credit, and women's groups have emerged in drought-prone areas in India with the objective of risk sharing among members. Where formal risk markets are not well developed, social capital can play a vital role for risk sharing and protecting households through informal insurance mechanisms (Carter and Maluccio 2003).

These mechanisms, however, are less effective in dealing with covariate risks that affect everybody within the community. Historical records of mass migration, starvation, and death attest to the failure of these informal mechanisms when droughts are severe and widespread. These informal arrangements that characterize traditional rural societies also seem to weaken considerably in the face of commercialization and greater exposure to the outside world (Jodha 1978).

Publicly sponsored relief programs can be effective in providing relief during catastrophic losses. The relief programs generally take the form of income transfer/employment generation although direct food distribution may also be a component when the drought is severe. To the extent that food insecurity is due to the lack of exchange entitlements, these relief programs are designed to transfer income to farmers in affected areas so that consumption deficits are reduced and excessive asset depletion is prevented. The strengths and weaknesses of various types of relief programs in terms of speed of response, coverage, and targeting have been discussed by Corbett (1988), Hay (1988), Dev (1996), Glauber and Collins (2002), and Owens et al (2003).

## 4. Economic consequences of coping mechanisms

The above discussion reveals that farm households are subject to a variety of idiosyncratic and covariate risks. Farmers in high risk-prone environments have, over time, developed a range of strategies to minimize risk and cope with losses when they occur.

Some of these coping strategies have proven effective and are helpful in reducing risk to some extent. At the same time, there is a substantial opportunity cost associated with these coping strategies. For example, by growing traditional rice varieties, farmers may be able to minimize drought risk but may end up sacrificing potential higher income in normal years. Also, poor farmers in high-drought-risk environments are reluctant to invest in seed-fertilizer technologies that could increase profitability in normal years but lead to a loss of capital investment in poor years. The climatic uncertainty often compels more risk averse farmers to employ conservative risk management strategies that reduce negative impact in poor years, but often at the expense of reducing average productivity and profitability and possibly contributing to a degradation of natural resources (Anderson 2001, Hansen 2002). Anderson (1995) estimated the economic cost of risk aversion to be around 20% of the average income. Likewise, Antle (1987) estimated the cost of risk aversion to be a 14% reduction in the expected net profit. Although the inefficiency cost may appear to be small in percentage terms, this involves a substantial reduction in the average income of poor farmers who are on or barely above the poverty line.

Overall, poor households use a number of informal insurance strategies to cope with drought. Some of these insurance strategies could, however, be very costly in terms of long-term opportunities for income growth. Poor households that are compelled to sell their productive assets may have difficulties building up their productive asset base. The low current investment in human capital by reducing spending on education and health care will impact on future income adversely. The impact of the crisis may be felt not just by the current generation but by the future generation as well. The loss of income and assets can convert transient poverty into chronic poverty (Morduch 1994). Public policy that effectively provides more efficient risk-coping mechanisms can contribute significantly to poverty reduction (Blomquist et al 2002, Owens et al 2003, Skoufia 2003).

## References


Alson M, Kent J. 2004. Social impacts of drought: a report to NSW Agriculture. Centre for Rural Social Research. New South Wales (Australia): Charles Sturt University.

AMS (American Meteorology Society). 1997. AMS policy statement on meteorological drought. Boston, Mass. (USA): AMS. Online at www.ametsoc.org.

Anderson JR. 1995. Confronting uncertainty in rainfed rice farming: research challenges. In: Fragile lives in fragile ecosystems. Proceedings of the International Rice Research Conference, 13-17 Feb. 1995. Manila (Philippines): International Rice Research Institute. p 101-108.

Anderson JR. 2001. Risk management in rural development: a review. Rural Development Strategy Background Paper 7. Rural Development Department. Washington, D.C. (USA): The World Bank.

Antle JM. 1987. Econometric estimation of producers' risk attitudes. Am. J. Agric. Econ. 69(3):509-522.

Ballabh V, Pandey S. 1999. Transitions in rice production systems in eastern India: evidences from two villages in Uttar Pradesh. Econ. Polit. Weekly March 27:11-16.

Bank of Thailand. 2005. The inflation report. January 2005. Bangkok (Thailand): The Bank of Thailand. 97 p.
Bardhan P, Udry C. 1999. Development microeconomics. Oxford (UK): Oxford University Press.
Barrett CB, Reardon T, Webb P. 2001. Nonfarm income diversification and livelihoods in rural Africa: concepts, dynamics, and policy implications. Food Policy 29(4):315-331.
Ben-Porath Y. 1980. The F-connection: families, friends, and firms and the organization of exchange. Pop. Dev. Rev. 6(1):1-30.
Binswanger HP, Rosenzweig MR. 1986. Behavioral and material determinants of production relations in agriculture. J. Dev. Stud. 22(3):503-539.
Blench R, Marriage Z. 1999. Drought and livestock in semi-arid Africa and southwest Asia. Overseas Development Institute (ODI) Working Paper 117. London (UK): ODI.
Blomquist J, Cordoba JP, Verhoeven M, Moser P, Bouillion C. 2002. Social safety nets in response to crisis: lessons and guidelines from Asia and Latin America. In: Towards Asia's sustainable development: the role of social protection. Paris (France): Organization of Economic Co-operation and Development. p 297-332.
Bourgeon JM, Chambers RG. 2003. Optimal area-yield crop insurance reconsidered. Am. J. Agric. Econ. 5:590-604.
Carter MR, Maluccio JA. 2003. Social capital and coping with economic shocks: an analysis of stunting of South African children. World Dev. 31(7):1147-1163.
Corbett J. 1988. Famine and household coping strategies. World Dev. 16(9):1099-1112.
Davies S. 1996. Adaptable livelihoods: coping with food insecurity in the Malian Sahel. New York, N.Y. (USA): St Martin's Press, Inc.
Dercon S. 2002. Income risk, coping strategies, and safety nets. The World Bank Research Observer 17(2):141-166.
Dev SM. 1996. Food security: PDS vs. EGS: a tale of two states. Econ. Polit. Weekly July:1752-1763.
Dilley M, Chen RS, Deichmann U, Lerner-Lam AL, Arnold M, Agwe J, Buys P, Kjekstad O, Lyon B, Yetman G. 2005. Natural disaster hotspots: a global risk analysis. Disaster Management Series. Hazard Management Unit. Washington, D.C. (USA): The World Bank and Columbia University.
Fafchamps M, Udry C, Czukas K. 1998. Drought and saving in west Africa: are livestock a buffer stock? J. Dev. Econ. 55(2):273-305.
Fafchamps M. 1992. Solidarity networks in pre-industrial societies: rational peasants with a moral economy. Econ. Dev. Cult. Change 41(1):147-174.
FAO (Food and Agriculture Organization of the United Nations). 2001. Report of the Asia-Pacific conference on early warning, prevention, and preparedness and management of disasters in floods and agriculture. Chiang Mai, Thailand, 12-15 June 2001. Bangkok (Thailand): FAO Regional Office for Asia and the Pacific (RAP) Publication No. 2001/14. Bangkok (Thailand): FAO/RAP.
FAO (Food and Agriculture Organization of the United Nations). 2002. Food supply situation and crop prospect in Sub-Saharan Africa (GIEWS). FAO/GIEWS: Africa Report No. 3, December 2002. Rome (Italy): FAO.
Findley SE. 1994. Does drought increase migration? A study of migration from rural Mali during the drought. Int. Migration Rev. 28:539-553.
Glauber JW, Collins KJ. 2002. Crop insurance, disaster assistance, and the role of federal government in providing catastrophic risk protection. Agric. Finance Rev. 62(2):81-101.
Glauber JW. 2004. Crop insurance reconsidered. Am. J. Agric. Econ. 86(5):1179-1195.

Hansen JW. 2002. Realizing the potential benefits of climate prediction to agriculture: issues, approaches, and challenges. Agric. Syst. 74:309-330.
Harrower S, Hoddinott J. 2004. Consumption smoothing and vulnerability. Food Consumption and Nutrition Division (FCND) Discussion Paper 175. Washington, D.C. (USA): International Food Policy Research Institute.
Hay RW. 1988. Famine incomes and employment: Has Botswana anything to teach Africa? World Dev. 16(9):1113-1125.
Hazell P, Oram P, Chaherli N. 2001. Managing droughts in low-rainfall areas of Middle East and North Africa. Environment and Production Technology Division (EPTD) Discussion Paper 78. Washington, D.C. (USA): International Food Policy Research Institute.
Hoogeveen, H. 2003. Evidence on informal insurance in rural Zimbabwe. J. Africa Econ. 11(2):249-278.
ISDR-UN (International Strategy for Disaster Reduction). 2005. Summary report on session 2.2 "A seamless approach to the global problem of drought." Thematic Cluster 2: "Risk identification, assessment, monitoring, and early warning." Kobe report. World Conference on Disaster Reduction, 18-22 January 2005, Kobe, Hyogo, Japan. Geneva (Switzerland): The United Nations.
Jodha NS. 1978. Effectiveness of farmers' adjustment to risk. Econ. Polit. Weekly 13(25): A38-A48.
Jodha NS. 1986. Common property resources and rural poor in dry regions of India. Econ. Polit. Weekly 21(27):1169-1181.
Kazianga H, Udry C. 2004. Consumption smoothing? Livestock, insurance, and drought in rural Burkina Faso. Economic Growth Center Discussion Paper No. 898. New Haven, Conn. (USA): The Yale University.
Kinsey B, Burger K, Gunning JW. 1998. Coping with drought in Zimbabwe: survey evidence on responses of rural households to risk. World Dev. 26(1):89-110.
Kochar A. 1999. Smoothing consumption by smoothing income: hours-of-work response to idiosyncratic agricultural shocks in rural India. Rev. Econ. Statistics 81(1):50-61.
Kshirsagar KG, Pandey S, Bellon MR. 1997. Farmer perceptions, varietal characteristics and technology adoption: the case of a rainfed rice village in eastern India. Social Sciences Division Discussion Paper 5. Los Baños (Philippines): International Rice Research Institute.
Kuhl JJ. 2002. Risk-coping strategies by agricultural households in developing countries: a taxonomy. Manuscript. Institute of Economics, University of Copenhagen and UNEP Collaborating Center on Energy and Environment, Denmark. Roskilde (Denmark): The University of Copenhagen.
Kumar D. 2005. Breeding for drought resistance. In: Muhammad A, Harris PJC, editors. Abiotic stress: plant resistance through breeding and molecular approaches. New York, N.Y. (USA): Food Products Press, an imprint of The Howarth Press, Inc. p 145-176.
Lazo, JA, Tapay NE. 1999. Social correlates of rainfed rice farmers' mechanisms to cope with drought. Philipp. Agric. Sci. 82(2):190-199.
Lim Y, Townsend RM. 1994. Currency, transaction patterns, and consumption smoothing: theory and measurement in International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) villages. Manuscript. Chicago, Ill. (USA): University of Chicago.
Loftas T, Ross J. 1995. Dimensions of need: an atlas of food and agriculture. Rome (Italy): The Food and Agriculture Organization of the United Nations.
Mahul O. 2001. Optimal insurance against climatic experience. Am. J. Agric. Econ. 83(3):593-604.

Matlon PJ. 1991. Farmer risk management strategies: the case of west-African semi-arid tropics. In: Holden D, Hazell P, Pritchard A, editors. Risk in agriculture. Proceedings of the Tenth Agriculture Sector Symposium. Washington, D.C. (USA): The World Bank. p 51-79.
Mishra PK. 1996. Agricultural risk, insurance and income: a study of the impact and design of India's comprehensive crop insurance scheme. Vermont (USA): Ashgate Publishing Co.
Morduch J. 1994. Poverty and vulnerability. Am. Econ. Rev. 84(2):221-225.
Morduch J. 2001. Consumption smoothing across space: testing theories of risk-sharing in the ICRISAT study region of south India. Paper presented at the World Institute for Development Economics Research, United Nations University. (UNU/WIDER) meeting on insurance against poverty, Helsinki, 15-16 June 2001. Helsinki (Finland): The UNU/WIDER.
Morduch J. 2005. Consumption smoothing across space: testing theories of risk-sharing in the ICRISAT study region of south India. In: Dercon S, editor. Insurance against poverty. Oxford (UK): Oxford University Press. p 38-56.
MWR (Ministry of Water Resources of China). 2004. Water resources in China: special issues published on 2 August 2004. Beijing (China): MWR. Online at www.mwr.gov.cn.
Newbery DMG, Stiglitz J. 1979. Sharecropping, risk sharing, and the importance of imperfect information. In: Roumasset JA, Boussard JM, Singh I, editors. Risk, uncertainty and agricultural development. New York, N.Y. (USA): Agricultural Development Council. p 311-340.
ODI (Overseas Development Institute). 2005. Aftershocks: natural disaster risk and economic development policy. ODI Briefing Paper November 2005. London (UK): ODI. Online at www.odi.org.uk.
Otsuka K, Chuma H, Hayami Y. 1992. Land and labor contracts in agrarian economies: theories and facts. J. Econ. Lit. 30:1965-2018.
Owens T, Hoddinott J, Kinsey B. 2003. Ex-ante and ex-post public responses to drought shocks: evidence and simulations from Zimbabwe. World Dev. 31(7):1239-1255.
PACS (Poorest Areas Civil Society). 2004. Drought in India: challenges and initiatives. New Delhi (India): PACS programs. Online at www.empowerpoor.org.
Pandey S, Sanamongkhoun M. 1998. Rainfed lowland rice in Laos: a socio-economic benchmark study. Los Baños (Philippines): International Rice Research Institute.
Pandey S, Singh HN, Villano RA. 1998. Rainfed rice and risk coping strategies: some microeconomic evidences from Eastern India. Paper presented at the IRRI-NCAP Workshop on Risk Management in Rainfed Rice Systems, New Delhi, India.
Paxson C, Chaudhury C. 1993. Consumption smoothing and income seasonality in rural India. Woodrow Wilson School, Development Studies Working Paper 173. Princeton, N.J. (USA): Princeton University.
Paxson C. 1992. Using weather variability to estimate the response of savings to transitory income in Thailand. Am. Econ. Rev. 82(1):15-33.
Platteau J. 1991. Traditional systems of social security and hunger insurance: past achievements and modern challenges. In: Ahmad E, Dreze J, Hills J, Sen A, editors. Social security in developing countries. Oxford (UK): Clarendon Press.
Qureshi AS, Mujeeb A. 2004. Analysis of drought coping strategies in Baluchistan and Sindh Provinces of Pakistan. IWMI Working Paper 86. Colombo (Sri Lanka): International Water Management Institute.
Ramaswami B, Roe TL. 2004. Aggregation in area-yield crop insurance: the linear additive model. Am. J. Agric. Econ. 86(2):420-431.

Rathore JS. 2004. Drought and household coping strategies: a case of Rajasthan. Indian J. Agric. Econ. 59(4):689-708.
Reardon T, Matlon P, Delgado C. 1988. Coping with household-level food insecurity in drought-affected areas of Burkina Faso. World Dev. 16(9):1065-1074.
Reuters. 2005. Asian drought affects millions, hits crops, exports. Reuters News Service, 7 March 2005. Bangkok (Thailand). Cited in Planet Ark: The world environmental news. Online at www.planetark.com/dailynewsstory.cfm. Accessed in July 2005.
Rosenzweig MR. 1988. Risk, implicit contracts, and the family in rural areas of low-income countries. Econ. J. 98:1148-1170.
Rosenzweig MR. 2001. Saving behavior in low-income countries. Oxford Rev. Econ. Policy 17(1):40-54.
Rosenzweig MR, Stark O. 1989. Consumption smoothing, migration, and marriage: evidence from rural India. J. Polit. Econ. 97(4):905-926.
Rosenzweig MR, Wolpin KI. 1993. Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: investments in bullocks in India. J. Polit. Econ. 101(2):223-244.
Shah A. 2001. Water scarcity induced migration: how far watershed projects can help? Econ. Polit. Weekly XXXVI (35):September.
Shah DC, Shah A. 2005. Migration in remote tribal areas: evidence from southwestern Madhya Pradesh. Indian J. Agric. Econ. 60(2):184-204.
Siddiq EA, Kundu DK. 1993. Production strategies for rice-based cropping systems in the humid tropics. In: Buxton DR et al, editors. International Crop Science 1, Crop Science Society of America.
Singh HN, Singh JN, Singh RK. 1995. Risk management by rainfed lowland rice farmers in Eastern India. In: Fragile lives in fragile ecosystems. Proceedings of the International Rice Research Conference, 13-17 February 1995. Los Baños (Philippines): International Rice Research Institute. p 135-148.
Skees J, Black JR, Barnett BJ. 1997. Designing and rating an area-yield crop insurance contract. Am. J. Agric. Econ. 79:430-438.
Skees J, Hazell P, Miranda M. 1999. New approaches to crop insurance in developing countries. Environment and Production Technology Division (EPTD) Discussion Paper 55. Washington, D.C. (USA): International Food Policy Research Institute.
Skees JR, Gober S, Varangis P, Lester R, Kalavakonda V. 2001. Developing rainfall-based index insurance in Morocco. World Bank Policy Research Working Paper 2577. Washington, D.C. (USA): The World Bank.
Skoufia E. 2003. Economic crises and natural disasters: coping strategies and policy implications. World Dev. 31(7):1087-1102.
Sweet J. 1998. Livestock-coping with drought: Namibia—a case study. Paper prepared for the grassland group of the crop and grassland service (AGPC) of FAO for the FAO/AGAP electronic conference on “Livestock-coping with drought.” Tsumeb (Namibia): Northern Region Livestock Development Project.
Thomas D, Beegle K, Frankenberg E, Sikoki B, Strauss J, Teruel G. 2004. Education in crisis. J. Dev. Econ. 74:53-85.
Townsend RM. 1994. Risk and insurance in village India. Econometrica 62:539-592.
Townsend RM. 1995. Consumption insurance: an evaluation of risk-bearing systems in low-income economies. J. Econ. Perspectives 9(3):83-102.
Turvey CG. 2001. Weather derivatives for specific event risks in agriculture. Rev. Agric. Econ. 23:333-351.

Umamaheswari K, Khader V. 2004. Health based coping mechanisms in drought prone areas. J. Family Welfare 50(1):42-47.
UNDP (United Nations Development Program). 2004. Reducing disaster risk: a challenge for development. A global report. Bureau for Crisis Prevention and Recovery. New York, N.Y. (USA): United Nations. Online at www.undp.org/bcpr.
Udry C. 1995. Risk and saving in northern Nigeria. Am. Econ. Rev. 85(5):1287-1300.
Varangis P. 2002. Innovative approach to cope with weather risk in developing countries. The Climate Report 2(2), Fall 2001. Climate Risk Solutions, Inc.
Walker TS, Jodha NS. 1986. How small farm households adapt to risk. In: Hazell P, Pomareda C, Valdes A, editors. Crop insurance for agricultural development: issues and experience. Baltimore, Md. (USA): Johns Hopkins University Press. p 17-34.
WB (The World Bank). 2000. Dynamic risk management and the poor: developing a social protection strategy for Africa. Human Development Group, the Africa Region. Washington, D.C. (USA): The World Bank.
WB. 2003. Karnataka crop insurance study. South Asia Region. Washington, D.C. (USA): The World Bank.
Wilhite DA, editor. 1993. Drought assessment, management, and planning: theory and case studies. Boston, Mass. (USA): Kluwer Academic Publishers.
Wilhite DA. 2000. Drought as a natural hazard: concepts and definitions. In: Wilhite DA, editor. Drought: a global assessment. London (UK): Routledge Publishers. p 3-18.
Wilhite DA, Glantz MH. 1985. Understanding the drought phenomenon: the role of definitions. Water Int. 10:111-120.
Wisner RN, Chase CA. 1984. World food trade and US agriculture 1960-1983. Ames, Iowa, World Food Institute. Ames, Iowa (USA): Iowa State University.

## Notes

*Authors' addresses:* S. Pandey, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines; H. Bhandari, Social Sciences Division, International Rice Research Institute, currently with Japan International Research Center for Agricultural Sciences, 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan.

CHAPTER 3
# Analytical framework

S. Pandey and H. Bhandari

The framework of this study involves a cross-country comparative analysis of the nature of drought, its economic consequences, and coping mechanisms. The three countries included in the study are China, India, and Thailand. This study focuses on the rainfed rice-growing areas of these countries, which differ in the incidence of drought, level of economic development, and social and policy contexts of rice production (Table 3.1). The per capita gross national income (GNI) is much higher in Thailand than in the other two countries. Both rice yields and the extent of production variability are also different across the countries. Agricultural production in the rainfed regions of India is still mainly subsistence-oriented but it is more commercially oriented in China and Thailand. The cross-country comparative approach, hence, is expected to generate greater insights into drought management issues than what would be possible from individual studies conducted separately. A common framework is used for all three countries, while ensuring that important specificities of each country are adequately captured.

**Table 3.1. General characteristics of the three countries in the study.**

| Characteristics | China | India | Thailand |
|---|---|---|---|
| Per capita GNI (US$) | 1,290 | 620 | 2,540 |
| Population below poverty line (%) | 10 | 25 | 10 |
| Population of study area (million)[a] | 155 | 88 | 21 |
| Average landholding (ha household$^{-1}$) | 1.48 | 1.4 | 2.3 |
| Share of agriculture in total GDP (%) | 14 | 25 | 9 |
| Share of agriculture in total employment (%) | 49 | 60 | 49 |
| Irrigated rice area (% of total rice area) | 93 | 50 | 20 |
| Rice yield (t ha$^{-1}$)[b] | 6.2 | 2.9 | 2.6 |
| CV of rice production (%)[c] | 5 | 18 | 10 |
| Annual rainfall (mm) | 1,200–1,400 | 1,000–1,300 | 1,100–1,500 |

[a]This refers to the total population of the provinces/states included in this study. [b]Rice yield was estimated using 2002-04 data, for the whole country. [c]Coefficient of variation (CV) was estimated using 1970-2003 data for the provinces/states included in this study.
Data sources: FAOSTAT (2005), WB (2005), CIA (2005), IRRI (2005).

**Table 3.2. Description of secondary data used in the study, three countries.**

| Country | Province/ state/zone[a] | Number of selected counties/districts/provinces[b] | Data period covered[c] |
|---|---|---|---|
| China | Guangxi | 10 | 1982-2001 |
| | Hubei | 10 | 1982-2001 |
| | Zhejiang | 10 | 1982-2001 |
| India | Chattisgarh | 7 | 1970-2002 |
| | Jharkhand | 6 | 1970-1999 |
| | Orissa | 13 | 1970-2002 |
| Thailand | Zone 1 | 6 | 1970-2002 |
| | Zone 2 | 8 | 1970-2002 |
| | Zone 3 | 2 | 1970-2002 |

[a]Province, state, and agroecological zone at the aggregate level and county, district, and province at the disaggregate level are used for this study in China, India, and Thailand, respectively. [b]Geographical size of province in northeast Thailand is similar to the size of districts in India. Over time, old districts/provinces were partitioned into new districts because of various administrative and/or political needs. This created a problem of constructing a consistent time-series database. This problem was handled by integrating the database of new districts/provinces into that of old districts/provinces. Thus, all the analysis in this study was based on the old districts/provinces that existed in 1970. [c]In some cases, recent data are available at the aggregate level only. So, data up to 2003 were used in the aggregate-level analysis in some cases.

Two main types of analyses are conducted to meet the objectives of the study. The first relates to the characterization of drought and estimation of the aggregate value of production loss resulting from drought. The second involves an assessment of the impact of drought at the farm household level and an analysis of coping mechanisms.

## 1. Aggregate-level analysis

The estimation of aggregate production loss involves analyzing published temporal data on rainfall and crop production. Province-(or state) and county-(or district) level data are used for this (Table 3.2). These data were also used to estimate the aggregate economic losses from drought by correlating drought events with crop production. Crop production data over a run of years covering both drought and nondrought years were used in this study as opposed to the usual practice of subjectively estimating production losses using either farmers' or researchers' subjective estimates of yield losses and probability of drought (Widawsky and O'Toole 1990, Hossain 1996, Gypmantasiri et al 2003).

### 1.1 Estimation of frequency and intensity of drought

Drought is defined here in terms of the deficiency of actual rainfall compared with long-term average (LTA) rainfall. Following a similar approach used by the Indian Meteorological Department (IMD) and other literature (Pandey et al 2000, DAC 2003), drought is considered to occur in a particular year if the annual rainfall is less than

80% of the LTA. The focus of this study is on rice, which is grown mainly during the monsoon season. Hence, in the context of this study, drought is considered to have occurred if rainfall during the monsoon season is less than 80% of the LTA for each country. The frequency of drought is estimated as the ratio of the number of drought years to the total number of years considered. Monthly rainfall data were used to characterize the nature and frequency of drought.

The effect of moisture on crop production varies not only according to the total rainfall but also according to the timing. Rice is particularly sensitive to drought during the reproductive and grain-filling period (Fischer and Fukai 2003). A shortfall in rain during planting time could lead to poor land preparation, delayed planting, and difficulties in weed control. Crop yields may suffer as a result. In extreme cases, farmers may simply abandon rice planting, which happened in India during the severe drought year of 2002.

The rice-growing season is divided into three growing stages (seasons) for assessing the incidence of drought during different periods and its impact on production. These are the early, medium, and late stage (season). The frequency of drought during each stage is estimated as the number of years in which rainfall is below 80% of the LTA for that particular stage.[1]

The effect of drought on rice production could also vary depending on its intensity. Hence, it is important to quantify the intensity of drought. Again, following the approach used by the IMD, the intensity of drought is defined as "moderate," "severe," or "calamitous." Drought is defined as calamitous if rainfall in a particular year is less than 50% of the LTA. When rainfall is in the range of 50–70% of the LTA, drought is defined as severe. Moderate drought refers to a situation when rainfall is 70–80% of the LTA value.

In addition to rainfall analysis, drought declarations made by local and national governments can also be used for identifying drought years. A specific year is considered to be a drought year if it has been so declared by the government. For example, state governments in India have well-institutionalized rules and guidelines for drought declarations. The government declares a certain year as a drought year for relief purposes when the impact of drought is severe. Both indicators (rainfall-based and government-declared) of drought are used for estimating the probability of drought.

## 1.2 Estimating the production impact of drought

Two specifications are used to estimate the aggregate impact of drought on crop production. The first involves the estimation of a continuous relationship between production and rainfall using the temporal data. Production is expected to suffer when rainfall is too little or too much. This effect can be captured by specifying production (Q) as a quadratic function of rainfall:

$$Q = a + bT + cR + dR^2 + u$$

[1]A limitation of this approach is that rainfall during these periods is assumed to be stochastically independent. This is a somewhat strong assumption, especially when the adjoining periods are considered.

where R is rainfall, T is a trend variable capturing the effect of technological changes, and *u* refers to the random error term with the usual regression properties. In the specification above, the coefficients *c* and *d* represent the response to rainfall. It is anticipated that $c>0$ and $d<0$. The combined effect of drought on both area and yield is captured in this specification. This equation is used to estimate the elasticity of production with respect to rainfall. Elasticity is defined as

$$E = \left(\frac{dQ}{dR}\right)\left(\frac{R}{Q}\right)$$

where ($dQ/dR$) denotes the first derivative of production with respect to rainfall and (R/Q) is the reciprocal of average production per unit of average rainfall. The elasticity E thus measures the percentage change in production resulting from one percentage change in rainfall, with percentages calculated relative to the sample averages. The estimated elasticity can be converted into a production loss using the following equation:

$$dQ = E\left(\frac{dR}{R}\right)Q$$

A production loss arising from a given percentage change in rainfall (i.e., dR/R) can be estimated using the above equation. The definition of drought used here is rainfall deficiency of at least 20% relative to the long-term average. The corresponding loss is then estimated as

$$dQ = E\,(0.2)\,Q$$

Losses can similarly be calculated for years with varying degrees of rainfall shortages. One of the advantages of using the model based on elasticity is that the total effect of drought on production can be easily decomposed into the effect on area and yield. It can be shown that production elasticity is the sum of area and yield elasticities.

Time-series data on area, yield, and production of rice are used to estimate the elasticity of area, yield, and production with respect to rainfall. The seasonal influence is captured by using early-season rainfall, late-season rainfall, and monsoon-season rainfall to estimate the area, yield, and production elasticities of rice, respectively.

In the second approach, a discrete drought dummy variable is specified in a linear trend equation on production. In this specification, drought results in a discrete downward shift in the intercept as indicated in Figure 3.1. The model is specified as

$$Q = a + bT + cD + u$$

As previously defined, T refers to the time trend that captures the effect of technological change and D is the drought dummy. The drought dummy variable takes the

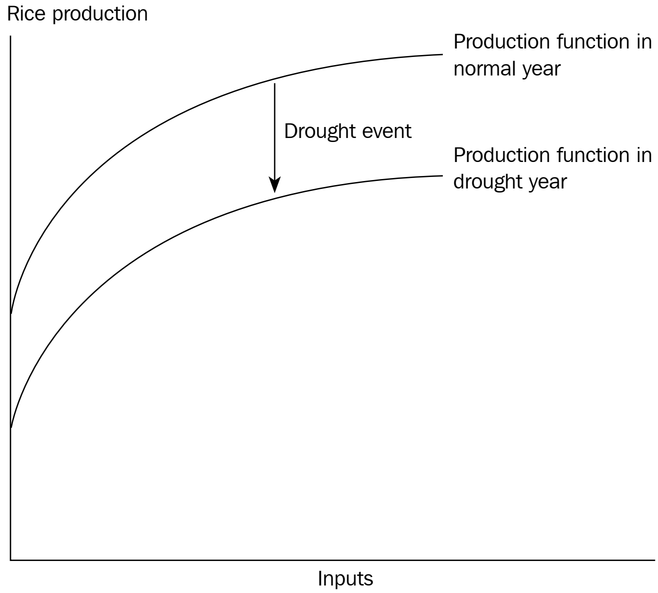



**Fig. 3.1. Production function showing the effect of drought on crop production.**

value of 1 in drought years and zero otherwise. The coefficient *c* measures the average effect of drought on production when all drought years are considered.

The production losses obtained above (i.e., based on elasticity or drought dummy) are estimates of losses averaged across drought years only. These losses need to be weighted by the probability (*P*) of drought to estimate the average loss per year (A) over a run of years. The estimated probability of drought is used for this purpose. Thus, the average annual loss is estimated as

$$A = \text{loss during drought} \times \text{probability of drought } (P)$$

The above specifications are also used to estimate the effect of drought on other important crops that are grown during the monsoon and postmonsoon seasons. Rainy-season crops are directly affected by a lack of rain, whereas post-rainy-season crops are affected by a reduced level of residual soil moisture. The value of the production losses for major nonrice crops is estimated using the dummy variable approach.

### 1.3 Household-level analysis

The analysis of the household-level impact of drought and farmers' coping mechanisms is conducted using cross-sectional data from a survey of farm households. For this, households were selected from study areas using a stratified random sampling approach. Detailed information on cropping patterns, rice production, household income, employment, and drought-coping mechanisms was elicited during the survey using pretested survey questionnaires.

The analysis of coping mechanisms ideally requires production, input use, consumption, and savings data for the same set of households over a number of years covering both drought and nondrought years. The use of such panel data permits a clear separation of production impact into impact resulting from variations in household characteristics and impact resulting from temporal drought effects (Walker and Ryan 1990, Townsend 1994, Morduch 2005). However, such panel data are not available in the context of this study.

The approach followed here, in the absence of panel data, is to isolate the drought effect by direct elicitation of the impact of drought and household responses. During the survey, farmers were asked to provide information on production practices and farm productivity for "normal" and "drought" years. Information on the overall impact of drought on income and how households attempted to cope with drought was also collected during the survey.

The meteorological definition of drought used for aggregate analysis is inappropriate for estimating the household-level impact. A village may suffer from drought in a particular year even though the meteorological data do not indicate drought at the aggregate (province/state/zone) level. Thus, a village-based identification of a normal and a drought year experienced in the recent past is needed. Such identification was made during the key-informant survey in each village selected (Table 3.3).

A drop in income during drought years can lead to a direct increase in the incidence of poverty. Some of this increase in the incidence of poverty may be "transient," that is, the affected people are able to quickly move back above the poverty line when the weather returns to normal. In other cases, this transient poverty may translate into "chronic" poverty. This can occur if drought results in asset depletion or other forms of disinvestments that prevent households from being able to make a full recovery. In either case, there will be a rise in the incidence of poverty. In addition, people who were poor even during normal years are likely to be pushed deeper into poverty. Thus, both the incidence and severity of poverty are likely to increase as a result of drought.

The effect of drought on poverty was analyzed using farm-level data on income. The effect of drought on the incidence and severity of poverty was analyzed using the standard Foster-Greer-Thorbecke (FGT) approach (Foster et al 1984). Poverty indices (head-count ratio, poverty gap index, squared poverty gap index) were compared between normal and drought years to illustrate the magnitude of drought impact on poverty.

How much reduction in poverty can be achieved through various strategies that reduce losses from drought? Answers to this question can provide some guidance on the desirable level of allocation of resources for drought mitigation. A simple scenario analysis was used to address this question. Drought mitigation strategies are assumed to reduce the loss in rice yield and/or area. Different assumptions regarding the magnitude of loss reduction were specified under alternative scenarios. These include a 50% and 100% reduction in yield loss, a 50% and 100% reduction in area loss, and

**Table 3.3. Sample selection schemes for the farm household survey, three countries.**

| Country | Province/ state/ zone | County/ district/ province | Township/ block/ district | Selected village | Number of households surveyed | Representative year | |
|---|---|---|---|---|---|---|---|
| | | | | | | Normal | Drought |
| **China** | Guangxi | Nandan | Dongjin | Heli | 30 | 2001 | 2000 |
| | | | Huopai | Huopai | 30 | 2001 | 2000 |
| | Hubei | Xiangyang | Yuli | Yuli | 31 | 2001 | 1999 |
| | | | Baxu | Baxu | 31 | 2001 | 1996 |
| | Zhejiang | Qingyuan | Hedi | Hedi | 31 | 2001 | n.a. |
| **India** | Chattisgarh | Kanker | Kanker | Echhapur, Aturgaon, Sigarbhat, Pidhapal, Malimohgaon | 100 | 1999 | 2002 |
| | | Mandla | Mandla | Dhauranala, Manadai, Khapakala | 100 | 1999 | 2002 |
| | | Raipur | Bhatapara | Tarenga, Datarangi, Kadar, Khamariya | 100 | 1999 | 2002 |
| | Jharkhand | Palamau | Chandwa<br>Daltonganj | Bhusaria, Sinkaru<br>Atre, Chetar | 78 | 2001 | 2000 |
| | | Santhal Parganas | Boarijore<br>Jarmundi | Sitalpur, Satiari<br>Baramra, Baratelo | 98 | 2001 | 2000 |
| | | Singhbhum | Patamda<br>Tonto | Shukla, Phuljharma<br>Dokata, Daudanga | 103 | 2001 | 2000 |
| | Orissa | Bolangir | Patnagarh | Dampal, Chindaguda | 97 | 2001 | 2002 |
| | | Dhenkanal | Odapada | Jogimunda, Jambahal | 98 | 2001 | 2002 |
| | | Nuapada | Khariar | Gundichapara, Haripur | 89 | 2001 | 2002 |
| **Thailand** | Zone 1 | Nong Khai | Fao Rai | Noan Meechai | 20 | 2000 | 1999 |
| | | Ubon Ratchathani | Sawang Weerawong | Nong Kaen Pattana | 20 | 2001 | 1996 |
| | Zone 2 | Buriram | Krasang | Ang Kruang | 20 | 1998 | 2000 |
| | | Khon Kaen | Nong Rue | Fang | 20 | 2001 | 1998 |
| | | Loei | Phu Rue | Lad Kang | 20 | 1999 | 2001 |
| | | Maha Sarakham | Kosum Phisai | Yang Sinchai | 20 | 1999 | 2001 |
| | | Nong Bua Lamphu | Sibun Rueng | Pa Ka | 20 | 2001 | 1999 |
| | | Roi Et | Kaset Visai | Noi Pattana | 20 | 2000 | 2001 |
| | | Udon Thani | Kumpa Wapi | Noan Hin Lad | 20 | 2001 | 2000 |
| | Zone 3 | Chaiyaphum | Chaturat | Kroak Pak Warn | 20 | 2000 | 2001 |
| | | | Kaset Somboon | Pi Puay | 20 | 2001 | 1999 |
| | | Khon Kaen | Wangnoi | Nong Ko | 20 | 2001 | 2000 |
| | | Nakhon Ratchasima | Dan Khuntot | Don | 20 | 2000 | 1998 |
| | | | Kang Sanamnang | Noan Rawieng | 20 | 2000 | 2001 |
| | | | Khonburi | Noan Klang | 20 | 2000 | 1997 |

a reduction in a combination of area and yield loss. The effect of a reduction in loss of rice production on income was estimated at the household level by assuming that income from all other sources during drought years remained unchanged.[2]

[2]This is a simplifying assumption. A reduction in production loss would be expected to result in resource allocation in favor of rice. By assuming that all other sources of income remain at their original drought-year value, household income is likely to be overestimated, resulting in a possible overestimation of poverty reduction.

## 1.4 Effectiveness of coping mechanisms

If farmers' coping strategies are ineffective/inefficient for stabilizing income and consumption, additional interventions through technology development and policy changes may be desirable. To judge the effectiveness of coping strategies, it is essential first to establish a norm against which the effectiveness can be assessed. One obvious indicator would be the extent to which farmers are able to smooth income and consumption. If long-term consumption is maintained at an acceptable level despite the production shocks, one can conclude that farmers have been effective in coping with risk. Similarly, if income levels have been maintained despite production shortfalls, ex ante coping strategies can be considered to have been effective. However, if farmers have adopted conservative production practices that stabilize consumption but at a lower average level, the reduction in average consumption provides a measure of the long-run cost of coping mechanisms. Thus, there are two components of the cost of coping. The first relates to the "transient" component of consumption and is measured by the extent of consumption shortfall during drought years. The lower the shortfall, the more effective the ex post risk-coping mechanisms will be. This measure is fairly easy to obtain through consumption surveys and is used in this study as an indicator of the effectiveness of coping with a reduction in income during drought years. The required information on consumption during normal and drought years was obtained during the survey.

The second measure relates to the long-run consumption level. Risk and risk aversion may lead to the choice of conservative strategies that reduce long-run income and consumption from what could be expected for a given resource base and technological options available. Coping mechanisms are more effective (or less costly) if the reduction in the average level of long-run consumption is smaller.

Estimation of the magnitude of the long-run reduction in consumption level as a result of drought requires a detailed investigation of risk, risk aversion, and their impact on household income. Complications arise as ex ante and ex post mechanisms can substitute for/complement each other. Farmers' choice of ex ante mechanisms may be conditional on what ex post mechanisms are available. For example, a relatively wealthy farmer who can draw upon savings to meet a production shortfall during years of low production is less likely to adopt conservative production practices. On the other hand, the effectiveness of ex post mechanisms may depend on the risk already averted by adopting conservative production practices (Morduch 1994). Thus, to measure the effectiveness of these strategies, both types of strategies need to be modeled simultaneously. Because of the complexity of such an exercise, a simple way is to obtain boundary estimates by assuming one of the mechanisms to be nonexistent. For example, upper-bound estimates of benefit from income-smoothing strategies are obtained if consumption smoothing is assumed away by equating consumption with income. Similarly, upper-bound estimates of benefit from consumption smoothing can be obtained if income smoothing is assumed away.

If consumption smoothing is assumed away, the benefit of ex ante coping strategies can be obtained as the sum of the change in mean income and the economic value of a reduction in instability. Based on Newbery and Stiglitz (1981), the benefit (X) measured as a proportion of total income can be expressed as

X = proportionate change in mean income (Y) +
proportional risk premium (RP)

The proportional risk premium is obtained as

$$RP = 0.5\ R\ [CV_1^2 - CV_0^2]$$

where R is the coefficient of relative risk aversion, $CV_1$ is the coefficient of variation of total income in the absence of ex ante strategies, and $CV_0$ is the coefficient of variation of total income when ex ante strategies are employed. Thus, P measures the economic value of a stability gain as a proportion of mean income. For a given level of relative risk aversion, the higher the gap between $CV_1$ and $CV_0$, the higher will be the potential benefit of stabilization. Farmers may be able to eliminate a lot of income variability by adopting conservative practices but this stability gain may be costly in terms of the forgone opportunities for raising mean income. The effectiveness can hence be judged by comparing these two components of net benefit.

A problem in applying the above equation is the difficulty of estimating $CV_1$ when farm survey data are used. Farm survey data already capture the effect of such strategies and hence underestimate the true $CV_1$. The coefficient of variation of realized income is a measure of the residual instability that farmers have been unable to reduce through ex ante risk management. The estimation of $CV_1$ may require the use of normative farm models (Hazell et al 1986), which have problems of their own in adequately capturing the complexity of farming systems in risky environments (Hardaker et al 1991). Another option may be to obtain $CV_1$ based on the production systems of farmers who behave as if they are risk-neutral. However, such farmers are also likely to have a more favorable resource base. The estimate of $CV_1$ derived from such farmers may not be applicable to others due to the confounding effects of variations in resource bases among farmers.

Given these difficulties in applying the model above, the cost of ex ante coping mechanisms is estimated here using a somewhat incomplete but simpler approach. Knowing that droughts are regular phenomena that cannot be predicted accurately, farmers would have evolved conservative practices that give them some safety even at the cost of a reduction in income during normal years. The cost of these conservative practices is the income forgone in the pursuit of safety. This forgone income is estimated by comparing the net income from fields that are drought-prone with that of fields that are better endowed in terms of moisture availability. The implicit assumption is that income from the fields with good moisture availability provides an estimate of the benchmark value that would be obtained from other fields also if they were not affected by drought. Drought is considered to be the main factor that constrains yield (and income) from these other fields.

## 2. Total economic costs of drought

Given the multidimensional nature of the effects of drought, estimating its total economic costs requires an assessment of the direct, indirect, and second-round effects of a drought event. The major components of cost are as follows: (1) the value of production losses during drought years, (2) the ex ante cost incurred by farmers in adopting conservative production practices and in making crop management adjustments, (3) the cost of drought relief provided by the government and other agencies,[3] (4) the cost of mitigation programs implemented to reduce production losses, (5) the second-round effects of drought on the economy, and (6) the value of long-term production losses arising from a depletion of farm and human capital during drought years.

The total economic cost estimated in this study includes the first four components, weighted by the respective probabilities to estimate the annual average cost. The last two cost items are not included due to the unavailability of suitable multiplier coefficients to translate direct production effects into these second-round effects. The estimates derived here represent a lower-bound value if the second-round effects are indeed substantial.

## References


CIA (Central Intelligence Agency). 2005. The world fact book. Accessed in January 2006. Online at www.odci.gov/cia/publications/factbook.

DAC (Department of Agriculture and Cooperation). 2003. Drought situation in the country. The forty-fifth report of the standing committee on agriculture submitted to the thirteenth Loksabha. December 2003. New Delhi (India): Department of Agriculture and Cooperation, Ministry of Agriculture.

FAOSTAT. 2005. FAOSTAT-agriculture. Statistical Database. Food and Agriculture Orgnization of the United Nations. Last accessed in February 2005. Online at http://faostat.fao.org.

Fischer KS, Fukai S. 2003. How rice responds to drought: breeding rice for drought-prone environments. In: Fischer KS, Lafitte R, Fukai S, Atlin G, Hardy B, editors. Breeding rice for drought-prone environments. Los Baños (Philippines): International Rice Research Institute. p 32-36.

Foster J, Greer J, Thorbecke E. 1984. A class of decomposable poverty measures. Econometrica 52(3):571-576.

Gypmantasiri P, Limnirankul B, Muangsu C, editors. 2003. Integration of farmer participatory plant breeding for rainfed lowland rice improvement in north and northeast Thailand. I. Biophysical and socio-economic characterization of rainfed lowland rice production systems of the north and the northeast of Thailand. Ubon (Thailand): Ubon Ratchathani Rice Research Center.

Hardaker JB, Pandey S, Patten LH. 1991. Farm planning under uncertainty: a review of alternative programming models. Rev. Marketing Agric. Econ. 59(1):9-22.


[3]This is a transfer payment component; hence, it is not strictly an economic cost. However, opportunity costs are likely to be incurred when scarce capital is used for providing relief.

Hazell P, Pomerada C, Valdes A. 1986. Crop insurance for agricultural development. Baltimore, Md. (USA): Johns Hopkins University Press.
Hossain M. 1996. Recent developments in the Asian rice economy: challenges for rice research. In: Evenson E, Herdt RW, Hossain M, editors. Rice research in Asia: progress and priorities. Wallingford (UK): CAB International. p 17-33.
IRRI (International Rice Research Institute). 2005. World rice statistics database. Los Baños (Philippines): IRRI. Online at www.irri.org/science/ricestat.
Morduch J. 1994. Poverty and vulnerability. Am. Econ. Rev. 84(2):221-225.
Morduch J. 2005. Consumption smoothing across space: testing theories of risk-sharing in the ICRISAT study region of south India. In: Dercon S, editor. Insurance against poverty. Oxford (UK): Oxford University Press. p 38-56.
Newbery DMG, Stiglitz J. 1981. The theory of commodity price stabilization: a study in the economics of risk. Oxford (UK): Oxford University Press.
Pandey S, Behura DD, Villano R, Naik D. 2000. Economic costs of drought and farmers' coping mechanisms: a study of rainfed rice systems in eastern India. IRRI Discussion Paper Series 39. Los Baños (Philippines): International Rice Research Institute. 35 p.
Townsend RM. 1994. Risk and insurance in village India. Econometrica 62:539-592.
Walker TS, Ryan JG. 1990. Village and household economies in India's semi-arid tropics. London (UK): Johns Hopkins University Press.
Widawsky DA, O'Toole JC. 1990. Prioritizing the rice biotechnology research agenda for Eastern India. New York, N.Y. (USA): The Rockefeller Foundation. 86 p.
WB (The World Bank). 2005. Ethiopia risk and vulnerability assessment. Report No. 26275-ET. Human Development Group III, Africa region. Washington, D.C. (USA): The World Bank.

## Notes

*Authors' addresses:* S. Pandey, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines; H. Bhandari, Social Sciences Division, International Rice Research Institute, currently with Japan International Research Center for Agricultural Sciences, 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan.

CHAPTER 4
# Economic costs of drought and rice farmers' drought-coping mechanisms in eastern India

H. Bhandari, S. Pandey, R. Sharan, D. Naik, I. Hirway, S.K. Taunk, and A.S.R.A.S. Sastri

## 1. Introduction

Agriculture is the mainstay of the Indian economy. It accounts for 24% of the gross domestic product (GDP) and 15% of total exports. It provides livelihood to 65% of the population and direct employment to 58% of the workforce (DAC 2004). Rice is the single most important food grain; it occupies 36% of the gross cropped area and accounts for 42% of the total food-grain production in India. The eastern Indian states of Uttar Pradesh, Chattisgarh, Bihar, Jharkhand, Assam, West Bengal, and Orissa are the major rice-growing areas, accounting for about half of the total rice production in the country. Much of this production is carried out under rainfed conditions. This makes rice production vulnerable to fluctuations in rainfall. The large drop in rice production in the past major drought years in eastern India attests to the fact that drought is one of the major constraints to increased and stable agricultural production in India (Widawsky and O'Toole 1990, Pandey et al 2000, Umamaheswari et al 2001, Hirway 2001, Singh and Ballabh 2002, Singh et al 2003, Verulkar 2003, DAC 2004, Samra 2004a). The severe drought of 2002 caused an 18% and 22% drop in total food-grain and rice production in India as a whole, respectively, as compared to 2001.

Drought has a direct causal effect on India's economic growth as agriculture contributes about one-fourth of GDP. This means that a 4-percentage-point decline in agricultural production would directly translate into a 1-percentage-point decline in GDP growth. Therefore, major droughts in India have been followed by a slowdown in GDP growth (PACS 2004). As a result of the severe drought of 2002, agricultural GDP growth decelerated by 5.2% vis-à-vis 2001. This decline in agricultural GDP translated into a reduction in GDP growth by 1.8 percentage points. Extreme droughts may lead to a shortage of water for domestic and other uses, a loss of livestock, a depletion of common resources such as forests and grazing land, withdrawal of children from school, and distress migration. The poorest are likely to be pushed further into poverty and become destitute.

In India, drought is a perennial phenomenon, recurring every few years. At least one or another region of the country is affected by drought of varying intensity almost every year. Historical data on the occurrence of drought are well documented. The country witnessed 40 droughts of varying intensity during 1876-2002 (Table 4.1). This translates into approximately a 31% probability of drought. This probability in different meteorological subdivisions in India is given in Table 4.2. It is evident from the table that most areas of the country are drought-prone and that the frequency of drought varies from once in two years to once in five years.

Almost 50% of the past drought occurrences were widespread and affected more than 30% of the country's area (Table 4.1). Seven were major droughts (1877, 1899, 1918, 1965, 1972, 1987, and 2002) that affected over 40% of the country's area. Samra (2004b) reported that, from 1900 to 2004, 1.4 billion people were affected, with cumulative damage of US$2.0 billion, and that, during the recent drought of 2002, a total relief of $4.6 billion alone was disbursed to 300 million affected people. Improved food availability and an improved distribution system, the integration of markets, better preparedness, and better governance almost eliminated starvation deaths during these latter droughts. However, postdrought consequences on human welfare are still substantial.

Over 68% of the agricultural area in India is considered to be vulnerable to drought (PACS 2004). The "chronically drought-prone" areas (around 33%) receive less than 750 mm of rainfall, whereas 35% of the area, classified as "drought-prone," receives rainfall of 750–1,125 mm. The drought-prone areas of the country are confined mainly to peninsular and western India—primarily arid, semiarid, and subhumid regions. The chronically drought-affected districts are listed in Table 4.3.

The overall objective of this study is to estimate the economic costs of drought and analyze the risk-coping mechanisms of farmers in drought-prone rice-growing areas of eastern India. The specific objectives of the study are as follows:

1. To understand the nature and magnitude of drought risk in drought-prone rice-growing areas of Chattisgarh, Jharkhand, and Orissa in eastern India;
2. To estimate the economic costs of drought at the aggregate level;
3. To estimate the economic costs of drought at the farm-household level and analyze farmers' drought-coping mechanisms;
4. To analyze the impact of drought on poverty; and
5. To suggest alternative options for technology and policy interventions for the effective management of drought risk.

This chapter is organized into ten sections. It begins with a general discussion of the nature of drought in the rice production systems of eastern India, followed by a short description of research design and data generation. The empirical findings of the study are presented in subsequent sections. Section 3 characterizes drought and estimates production losses at the aggregate level. Sections 4 to 6 focus on the household-level impacts of drought and farmers' drought-coping mechanisms. The agricultural employment effect and total economic costs of drought are estimated for drought-prone rainfed rice environments of three selected states of eastern India in Section 7. A simple simulation analysis of the poverty impact of drought mitigation follows in Section 8. A critical overview of policies and institutional setup for drought

**Table 4.1. Years of drought in India, 1876-2002.**

| Drought year | Area affected (million km²) | Area affected (% area of the country) | Category | Ranking |
|---|---|---|---|---|
| 1876 | 0.49 | 16 | Slight | 35 |
| 1877 | 2.03 | 65 | Calamitous | 2 |
| 1883 | 1.03 | 33 | Moderate | 14 |
| 1884 | 0.70 | 22 | Slight | 27 |
| 1885 | 0.48 | 15 | Slight | 36 |
| 1891 | 1.15 | 37 | Moderate | 10 |
| 1896 | 0.68 | 22 | Slight | 28 |
| 1899 | 1.99 | 63 | Calamitous | 3 |
| 1901 | 0.89 | 29 | Moderate | 21 |
| 1902 | 0.54 | 17 | Slight | 34 |
| 1904 | 0.98 | 31 | Moderate | 17 |
| 1905 | 1.09 | 35 | Moderate | 11 |
| 1907 | 0.85 | 27 | Slight | 23 |
| 1911 | 0.97 | 31 | Moderate | 18 |
| 1913 | 0.70 | 22 | Slight | 26 |
| 1915 | 0.63 | 20 | Slight | 31 |
| 1918 | 2.16 | 69 | Calamitous | 1 |
| 1920 | 1.22 | 39 | Moderate | 9 |
| 1925 | 0.80 | 26 | Slight | 25 |
| 1928 | 0.67 | 21 | Slight | 29 |
| 1936 | 0.86 | 28 | Slight | 22 |
| 1941 | 1.01 | 32 | Moderate | 16 |
| 1951 | 1.04 | 33 | Moderate | 12 |
| 1952 | 0.81 | 26 | Slight | 24 |
| 1965 | 1.35 | 43 | Moderate | 7 |
| 1966 | 1.01 | 32 | Moderate | 15 |
| 1968 | 0.45 | 21 | Slight | 30 |
| 1969 | 0.62 | 20 | Slight | 32 |
| 1971 | 0.42 | 13 | Slight | 37 |
| 1972 | 1.39 | 44 | Severe | 6 |
| 1974 | 0.92 | 29 | Moderate | 20 |
| 1979 | 1.24 | 39 | Moderate | 8 |
| 1982 | 1.04 | 33 | Moderate | 13 |
| 1985 | 0.95 | 30 | Moderate | 19 |
| 1986 | 0.60 | 19 | Slight | 33 |
| 1987 | 1.55 | 49 | Severe | 5 |
| 1988[a] | n.a.[c] | n.a. | Moderate | n.a. |
| 1993[a] | n.a. | n.a. | Moderate | n.a. |
| 2000[b] | n.a. | n.a. | Moderate | n.a. |
| 2002[b] | 1.84 | 56 | Severe | 4 |

[a]Nagarajan (2003). [b]Samra (2004a). [c]n.a. means information not available.
Data sources: The Fertilizer Association of India (2002-03).

**Table 4.2. Probability of occurrence of drought in different meteorological subdivisions, India.**

| Meteorological subdivision | Frequency of deficient rainfall (75% of normal or less) |
|---|---|
| Assam | Very rare, once in 15 years |
| West Bengal, Madhya Pradesh, Konkan, Bihar, and Orissa | Once in 5 years |
| South Interior Karnataka, eastern Uttar Pradesh, and Vidarbha | Once in 4 years |
| Gujarat, East Rajasthan, and western Uttar Pradesh | Once in 3 years |
| Tamil Nadu, Jammu and Kashmir, and Telengana | Once in 2.5 years |
| West Rajasthan | Once in 2.5 years |

Source: UNDP (2003).

**Table 4.3. Administrative districts chronically affected by drought conditions, India.**

| State | Districts |
|---|---|
| Andhra Pradesh | Anantpur, Chittoor, Cuddapah, Hyderabad, Karnool, Mehboobnagar, Nalgonda, and Prakassam |
| Bihar | Aurangabad, Bhojpur, Gaya, Munger, Nawadah, and Rohtas |
| Gujarat | Ahmedabad, Amrely, Banaskantha, Bhavnagar, Bharuch, Jamnagar, Kheda, Kutch, Mehsana, Panchmahal, Rajkot, and Surendranagar |
| Haryana | Bhiwani, Gurgaon, Mahendranagar, and Rohtak |
| Jammu and Kashmir | Doda and Udhampur |
| Karnataka | Bangalore, Belgaum, Bellary, Bijapur, Chitradurga, Chickmagalur, Dharwad, Gulbarga, Hassan, Kolar, Mandya, Mysore, Raichur, and Tumkur |
| Madhya Pradesh | Betul, Datia, Dewas, Dhar, Jhabhua, Khandak, Shahdol, Shahjapur, Sidhi, and Ujjain |
| Maharashtra | Ahmednagar, Aurangabad, Beed, Nanded, Nashik, Osmanabad, Pune, Parbhani, Sangli, Satara, and Solanpur |
| Orissa | Bolangir, Kalahandi, Kendrapada, and Phulbani |
| Rajasthan | Ajmer, Banaswada, Barmer, Churu, Dungarpur, Jaisalmer, Jalore, Jhunjunu, Jodhpur, Nagaur, Pali, and Udaipur |
| Tamil Nadu | Coimbatore, Dharmapuri, Madurai, Ramanathapuram, Salem, Tiruchirapali, Tirunelveli, and Kanyakumari |
| Uttar Pradesh | Allahabad, Banda, Hamirpur, Jalan, Mirzapur, and Varanasi |
| West Bengal | Bankura, Midnapore, and Purulia |
| Jharkhand | Palamau |

Sources: Nagarajan (2003) and PACS (2004), the latter for Jharkhand.

management in India is provided in Section 9. The final section summarizes the major findings of the study and concludes with a discussion of the overall implications for technology design and policy improvements for longer-term drought mitigation and relief in the context of India.

## 2. Research design and data generation

This study focuses on eastern India. Three drought-prone states (Chattisgarh, Jharkhand, and Orissa) in eastern India are purposively selected. Two types of analysis are conducted to meet the objectives of the study. The first involves the analysis of published temporal data on rainfall and crop production. District-level temporal data covering the period of 1970-2003 on monthly rainfall as well as rice and nonrice crop production are used for this.[1] Characterization of the timing, intensity, frequency, and spatial pattern of drought is conducted using district-level monthly rainfall data. These data are also used to estimate the aggregate economic losses from drought by correlating drought events with production.

Drought is defined in terms of deficiency of actual rainfall compared with long-term average (LTA) rainfall. Following the approach used by the Indian Meteorological Department, drought is considered to have occurred if rainfall during the monsoon season (June-October) is less than 80% of the LTA. The rice-growing season is divided into three periods—the early season (June-July), the mid season (August), and the late season (September-October)—for assessing the incidence of drought during different periods and its impact on production. The frequency of drought during each period is estimated as the number of years in which rainfall is below 80% of the LTA for that particular period.

The basic analytical approach followed is described in Chapter 3. Two specifications are used to estimate the aggregate impact of drought on rice production. The first involves the estimation of a continuous relationship between production and rainfall using historical data. Production is expected to suffer when rainfall is too little or too much. This effect can be captured by specifying production (Q) as a quadratic function of rainfall:

$$Q = a + bT + cR + dR^2 + u \qquad (1)$$

where R is rainfall, T is a trend variable capturing the effect of technological changes, and $u$ refers to the random error term with the usual regression properties. In the specification above, the coefficients $c$ and $d$ measure the response to rainfall. It is anticipated that $c>0$ and $d<0$. This above equation can be used to estimate the elasticity of production with respect to rainfall.

In the second specification for estimating production losses due to drought, a discrete drought dummy variable is specified in a linear trend equation. The model is specified as

$$Q = a + bT + cD + u \qquad (2)$$

[1]Over time, old districts were partitioned into new districts in response to administrative requirements and/or political need. This created a problem in constructing time-series data while keeping track of changes in the number of districts. This problem was handled by integrating the database of new districts into that of old districts. Thus, all analysis in this study is based on the old districts that existed in 1970.

As previously defined, T refers to the time trend that captures the effect of technological change and D is the drought dummy, which can be specified separately for different seasons. The drought dummy variable takes the value of 1 in drought years and zero otherwise. The coefficient *c* measures the average effect of drought on production when all drought years are considered.

The drought dummy is identified using two approaches. In the rainfall-based approach, a specific year is considered to be a drought year if the rainfall deficiency in that year is over 20% of LTA. Drought years may also be identified using drought declarations made by the government. A specific year is considered to be a drought year if it has been declared by the government as a drought year. Equation (2) is hence estimated using both a rainfall-based and government-declared drought dummy.

The production loss estimated above (based on rainfall or drought dummy) measures the average loss for drought years *only*. This needs to be weighted by the probability of drought to estimate the average loss *per year* over a run of years. The probabilities of drought estimated from both rainfall-analysis and government-declared droughts are used for this purpose.

The above specifications are also used to estimate the effect of drought on other important crops that are grown during the monsoon and postmonsoon seasons. The major nonrice crops that are affected by drought in the states under study are pulses and oilseeds (Pandey et al 2000). Rainy-season crops are directly affected by a lack of rain whereas the post-rainy-season crops are affected by a reduced level of residual soil moisture. The value of the production losses of these major nonrice crops is estimated using the dummy variable approach.

The second type of analysis involves the investigation of the household-level effects of drought and farmers' coping mechanisms using farm household survey data. For this, households were selected from each of the three states using a stratified random sampling approach from districts purposefully selected to be representative of the drought-prone environment. A total of 863 farmers were surveyed from the three states. The details of sampling design are provided in Table 4.4. In addition to survey questionnaires, a participatory rural appraisal, key-informants survey, focus group discussions, and case studies were conducted to collect qualitative information to complement the quantitative data. The survey was conducted in different periods during 2002. Missing data, however, were collected until the end of 2003. Both secondary and primary data analysis were done separately for each state.

## 3. Aggregate-level analysis

This section describes the trends in rice production as well as characteristics of rainfall and frequency of drought occurrence in eastern India. In addition, the rainfall elasticity of rice production and production losses of rice and major nonrice crops due to drought at the aggregate level are discussed using time-series data from 1970 to 2002. The results and discussion are based on aggregate (district or state)-level analysis.

**Table 4.4. Sample selection scheme, eastern India.**

| State | Districts | Blocks | Villages | Number of households surveyed |
|---|---|---|---|---|
| Chattisgarh | | | | |
| | Raipur | Bhatapara | Tarenga, Datarangi, Kadar, Khamariya | 100 |
| | Kanker | Kanker | Echhapur, Aturgaon, Sigarbhat, Pidhapal | 100 |
| | Mandla | Mandla | Malimohgaon, Dhauranala, Manadai, Khapakala | 100 |
| Jharkhand | | | | |
| | Singhbhum | Patamda, Tonto | Shukla, Phuljharna, Dokata, Daudanga | 103 |
| | Palamau | Chandwa, Daltonganj | Bhusaria, Sinkaru, Arde, Chetar | 78 |
| | Santhal Parganas | Boarijore, Jarmundi | Sitalpur, Satiari, Baramra, Baratelo | 98 |
| Orissa | | | | |
| | Nuapada | Khariar | Dampal, Chindaguda | 89 |
| | Bolangir | Patnagarh | Jogimunda, Jambahal | 97 |
| | Dhenkanal | Odapada | Gundichapara, Haripur | 98 |

**Table 4.5. Triennium average area, yield, and production of rice, eastern India, 2000-03.[a]**

| State | Area (million ha) | Yield[b] ($t\ ha^{-1}$) | Production[b] (million t) |
|---|---|---|---|
| Assam | 2.58 | 2.27 | 5.87 |
| Bihar | 3.59 | 2.23 | 8.02 |
| Jharkhand | 1.46 | 2.00 | 2.89 |
| Chattisgarh | 3.77 | 1.71 | 6.43 |
| Eastern Uttar Pradesh | 3.12 | 3.18 | 9.92 |
| Orissa | 4.48 | 2.07 | 9.28 |
| West Bengal | 5.79 | 3.65 | 21.17 |
| Eastern India | 25.51 | 2.53 | 64.61 |
| All India | 44.04 | 3.03 | 133.30 |

[a]Year 2002 was a severe drought and hence this year is excluded when estimating the average values. [b]Rice yield and production are expressed in terms of rough rice (i.e., unhusked paddy) using the conversion factor of 1 kg of unhusked paddy = 0.67 kg of milled rice.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

## 3.1 Trends in rice yield and production in eastern India

During 2000-03, rice in eastern India accounted for 58% and 48% of the total rice area and production in India, respectively (Table 4.5). During the period, rice area and production in eastern India were 25.5 million ha and 64.6 million tons, with an average yield of 2.5 t $ha^{-1}$. Eastern Uttar Pradesh and West Bengal have relatively high yields and account for close to half of the total rice production in eastern India.[2] Rice yields in Jharkhand, Chattisgarh, and Orissa, on the other hand, are relatively low.

[2]India's statistical systems report rice yields and production in terms of milled rice. In this report, these variables are expressed in terms of rough rice (i.e., unhusked paddy) using the conversion factor of 1 kg of unhusked paddy = 0.67 kg of milled rice.

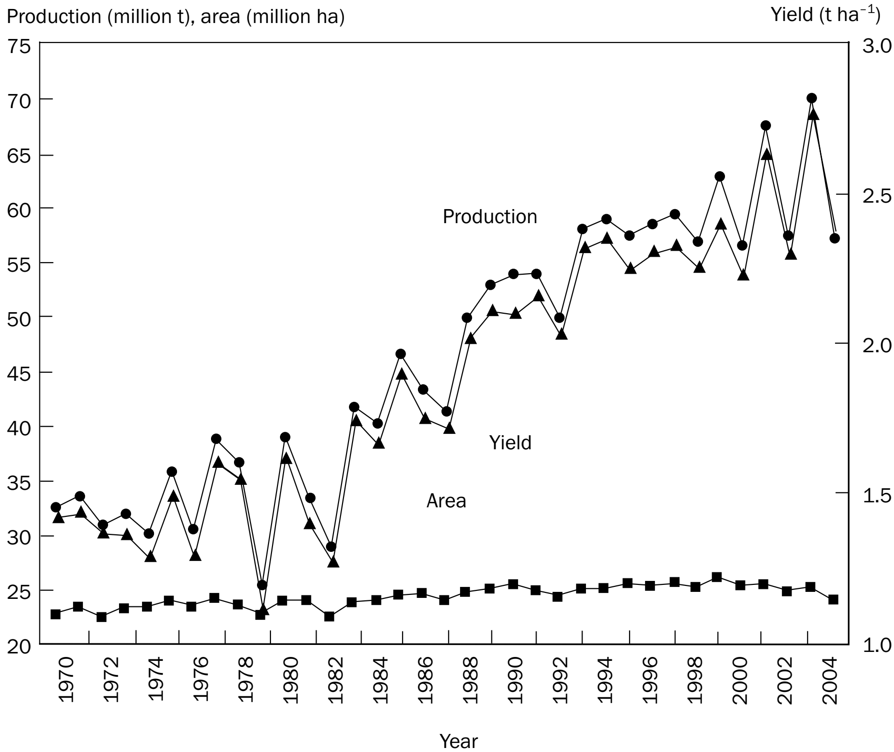



**Fig. 4.1. Rice area, yield, and production in eastern India, 1970-2004. Data source: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).**

Rice yield and production almost doubled in eastern India between 1970 and 2003 (Fig. 4.1). Up until 1981, the modest growth in output in eastern India was driven mainly by an expansion in area, with yield remaining more or less constant. However, yield growth picked up after 1981 and is now clearly the major source of growth in output. During 1970-2003, rice production in eastern India grew at 2.6% per annum, with yield growth accounting for 86% of this production growth (Table 4.6). Despite the achievement at the aggregate level, the growth has been quite variable across states.

During 1990-2003, almost all of the area having yield in the range of 1–2 t ha$^{-1}$ was concentrated in Bihar, Jharkhand, Chattisgarh, and Orissa (Table 4.7, Fig. 4.2). In these states, the proportionate area with yield in this range was above 60%. Given that Bihar, Jharkhand, Chattisgarh, and Orissa account for over 50% of the total rice area in eastern India, growth in productivity in these states is critical to the overall productivity performance of eastern India. The bulk of this low-productivity area is drought-prone. The incidence of poverty in these drought-prone states is also relatively high (Fig. 4.3). Although the incidence of poverty has decreased over time in all states, the decrease is much slower in these drought-prone areas relative to other states.

**Table 4.6. Compound annual growth rates (%) of rice area, yield, and production, eastern India, 1970-2003.**

| State/region | Area[a] | Yield | Production |
|---|---|---|---|
| Assam | 0.74*** | 1.50*** | 2.25*** |
| Bihar | –0.01 | 1.90*** | 1.89*** |
| Jharkhand | –0.64*** | 1.39*** | 0.74 ** |
| Chattisgarh | 0.78*** | 1.38*** | 2.15*** |
| Eastern Uttar Pradesh | 0.73*** | 4.03*** | 4.76*** |
| Orissa | 0.01 | 1.46*** | 1.48*** |
| West Bengal | 0.57*** | 2.63*** | 3.20*** |
| Eastern India | 0.35*** | 2.20*** | 2.55*** |
| All India | 0.50*** | 2.11*** | 2.61*** |

[a]***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

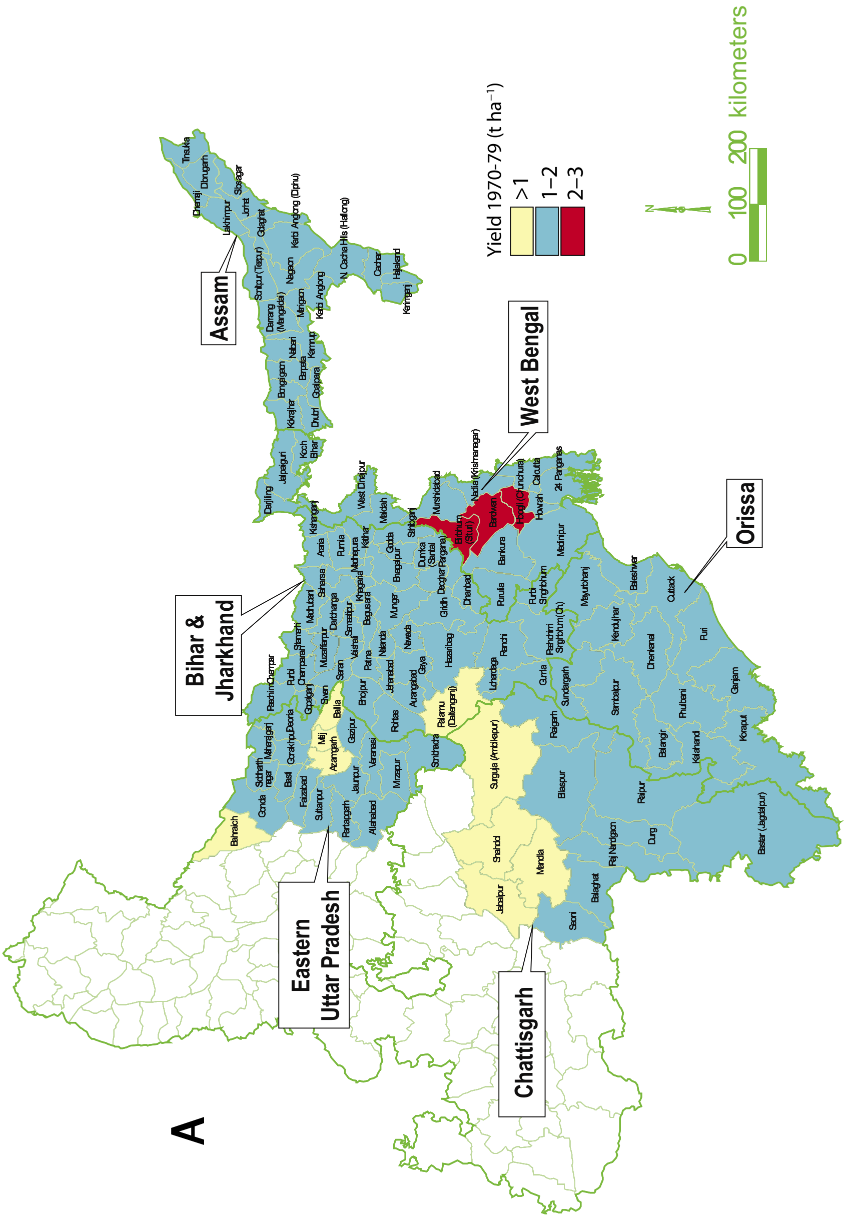
**Table 4.7. Average rice yield (t ha$^{-1}$), eastern India, 1970-2003.**

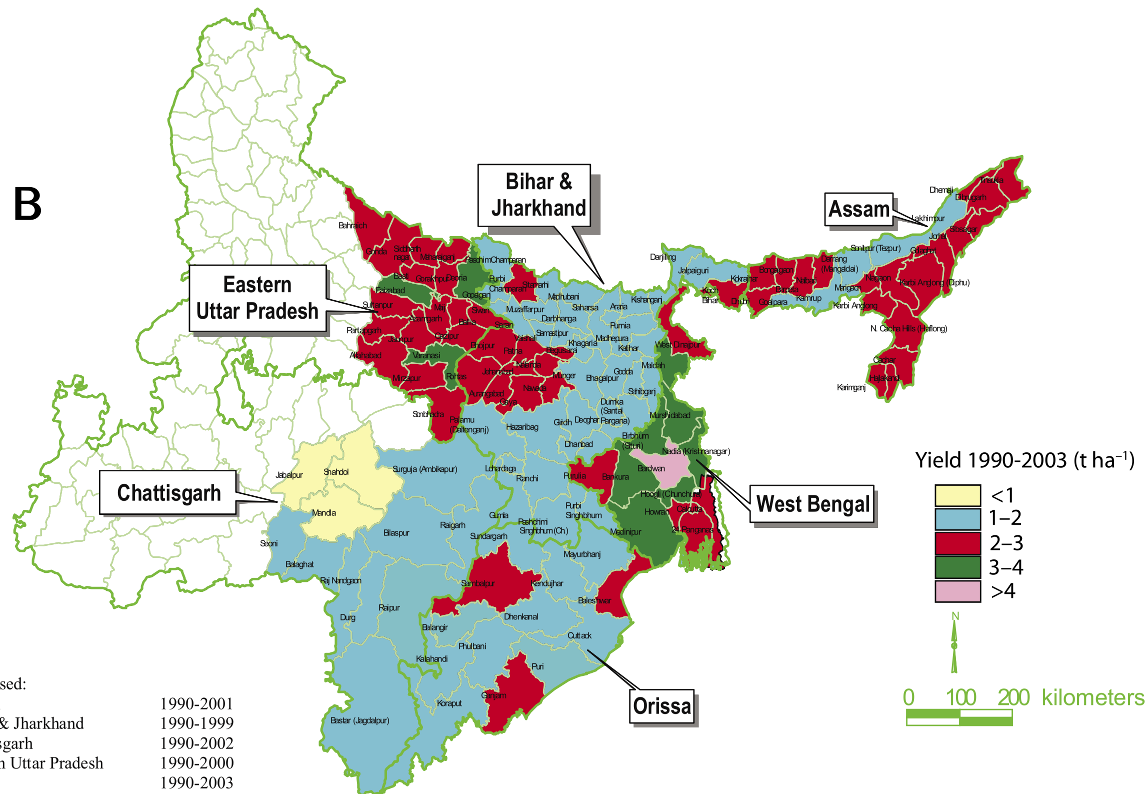
| State/region | Average yield | | | | Yield gain between 1970-72 and 2000-03 (kg y$^{-1}$) |
|---|---|---|---|---|---|
| | 1970-72 | 1980-82 | 1990-92 | 2000-03[a] | |
| Assam | 1.51 | 1.61 | 1.94 | 2.27 | 25 |
| Bihar | 1.43 | 1.32 | 1.58 | 2.23 | 26 |
| Jharkhand | 1.20 | 1.08 | 1.22 | 2.00 | 26 |
| Chattisgarh | 1.24 | 1.22 | 1.77 | 1.71 | 15 |
| Eastern Uttar Pradesh | 1.06 | 1.43 | 2.46 | 3.18 | 68 |
| Orissa | 1.32 | 1.34 | 1.94 | 2.07 | 24 |
| West Bengal | 1.84 | 1.79 | 2.95 | 3.65 | 59 |
| Eastern India | 1.41 | 1.44 | 2.10 | 2.53 | 36 |
| All India | 1.67 | 1.94 | 2.62 | 3.03 | 44 |

[a]There was a severe drought in 2002 and hence this year is excluded when estimating average values.
Rice yield and production are expressed in terms of rough rice (i.e., unhusked paddy) using the conversion factor of 0.67 kg rough rice to 1 kg of unhusked paddy.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

## 3.2 Rainfall and drought characteristics

The LTA annual rainfall for the three states varies from 1,214 mm in Chattisgarh to 1,335 mm for Orissa (Table 4.8). The monsoon rains start in June, peak during July and August, and taper off in October (Fig. 4.4). The distribution of overall average annual rainfall for the three states is 41% in the early season, 26% in the mid season, 23% in the late season, and 10% in the rest of the year (November-May). Thus, about 90% of the annual rainfall occurs during the monsoon season. Spatial variability in rainfall is considerable across districts. The spatial distribution of rainfall indicates that the LTA tends to increase in a west-east direction, with rainfall being relatively higher in the coastal belts of Orissa (Fig. 4.5).


A
Assam
West Bengal
Bihar &
Jharkhand
Eastern
Uttar Pradesh
Chattisgarh
Orissa
Yield 1970-79 (t ha$^{-1}$)
>1
1–2
2–3
N
0
100
200
kilometers




| Data used: | |
|---|---|
| Assam | 1990-2001 |
| Bihar & Jharkhand | 1990-1999 |
| Chattisgarh | 1990-2002 |
| Eastern Uttar Pradesh | 1990-2000 |
| Orissa | 1990-2003 |
| West Bengal | 1990-2000 |

**Fig. 4.2. Changes in rice productivity in different districts of eastern India, from 1970-79 (A) to 1990-2003 (B).**

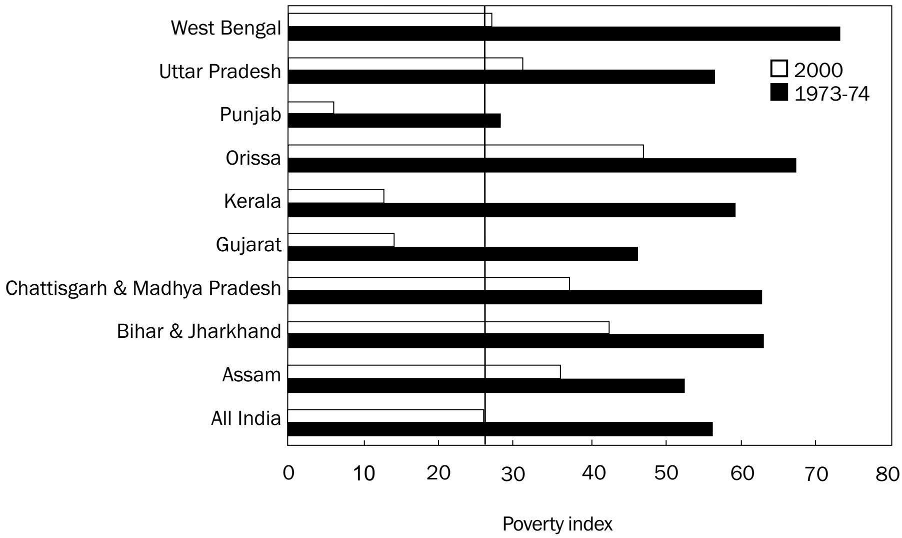



**Fig. 4.3. Incidence of poverty in India. Data sources: NIRD (2000) and Planning Commission (2002b).**

**Table 4.8. Long-term average rainfall (mm), eastern India, 1970-2003.[a]**

| State | Early | Mid | Late | Monsoon | Annual |
|---|---|---|---|---|---|
| | | Long-term average rainfall (mm) | | | |
| Chattisgarh | 536 | 345 | 255 | 1,136 | 1,214 |
| Jharkhand | 529 | 303 | 315 | 1,147 | 1,286 |
| Orissa | 516 | 343 | 308 | 1,167 | 1,335 |
| | | Coefficient of variation (%) | | | |
| Chattisgarh | 24 | 19 | 40 | 17 | 16 |
| Jharkhand | 28 | 25 | 34 | 17 | 16 |
| Orissa | 26 | 23 | 35 | 18 | 19 |

[a]Rainfall season is defined as early: June-July; mid: August; late: September-October; and monsoon: June-October. Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

The temporal variability of rainfall, as measured by the coefficient of variation (CV), is almost the same at 16% in Chattisgarh and Jharkhand but is slightly higher in Orissa at 19%. The higher variability of rainfall in Orissa is also indicated in the pattern of temporal fluctuations (Fig. 4.6A, 4.6B, and 4.6C). Across districts, the CV varies between 16% and 29%. The spatial pattern of variability in rainfall indicates that there is some association between low average rainfall and higher instability as measured by the CV (Fig. 4.7). Thus, the western inland districts not only have low mean rainfall but also higher variability relative to the eastern districts closer to the

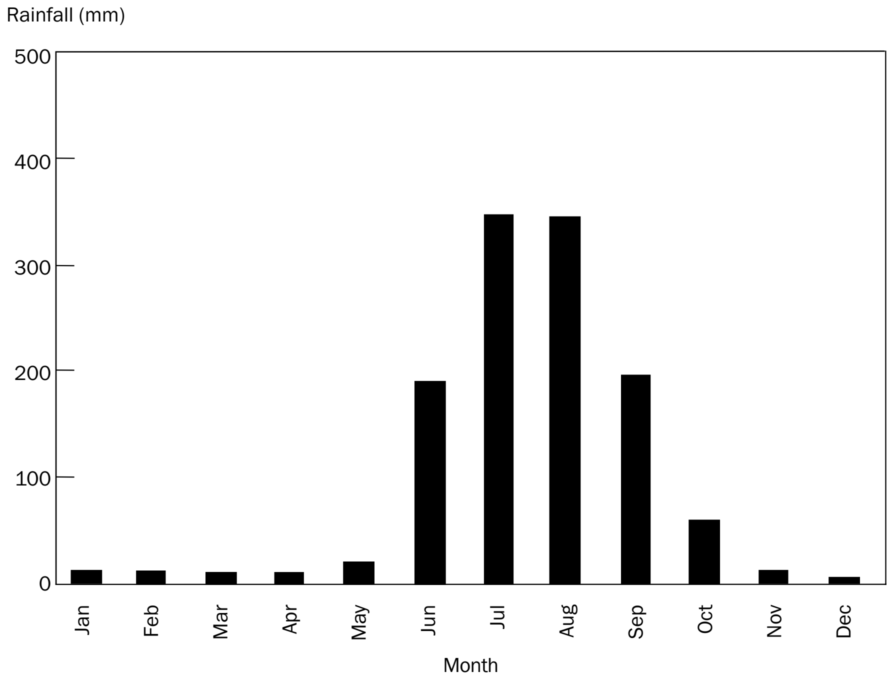



**Fig. 4.4. Monthly long-term average rainfall, Chattisgarh, 1970-2003.**

coastal belt. This pattern of spatial distribution and variability of rainfall is partly the result of the monsoon that starts in the coastal belt and moves inland. Obviously, the local topography and landforms modify this general pattern of rainfall gradient as the monsoon clouds move northwest over land.

The variability of rainfall is highest for the late season, which represents the terminal phase of rice growth (Table 4.8). Rice yield is very sensitive to moisture stress during this phase. The second-highest variability of rainfall is observed in the early season, which is the main crop establishment period for rice. Rainfall data from eastern Indian states thus indicate that rice is likely to experience large fluctuations in moisture regime during the reproductive/grain-filling and initial crop establishment stages.

The frequency of drought estimated using the meteorological definition of drought discussed in Section 2 is summarized in Table 4.9. The probability of monsoon-season drought for Chattisgarh, Jharkhand, and Orissa is 15%, 18%, and 21%, respectively. The estimated probabilities of drought for different seasons are reported in Table 4.10. The results indicate that the average probability (averaged across all districts of each state) of late-season drought for each state is approximately 1/3. The probability of early-season drought is slightly lower at 1/5 to 1/4. The spatial distribution of early-season drought probability does not indicate any clear pattern. The probability of late-season drought is higher in Chattisgarh than in the other two states. In Orissa,

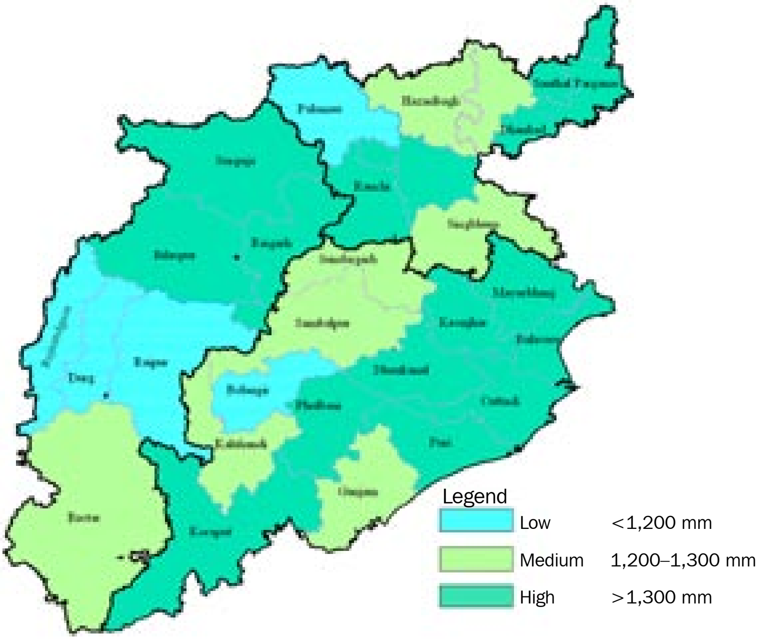



**Fig. 4.5. District-level long-term average rainfall, eastern India, 1970-2002.**

the coastal districts have a lower probability of terminal drought but the probability increases with movement toward inland districts. It was found earlier that the average rainfall tends to decrease in the northwestern direction. The probability of terminal drought is thus higher in areas with low average rainfall (Fig. 4.8).

This frequency of drought estimated from rainfall analysis is compared with that derived from government-declared drought events (Table 4.9). Although there is a good overlap of the identified drought years using both methods, the overlap is not complete. The number of drought years identified using the rainfall-based estimates is lower than when using the government-declared drought years. The effect of non-uniform temporal distribution of rain during the rice-growing season is unlikely to be captured in the rainfall-based definition used here. Some years in which crops suffer from moisture deficit during a specific period will not be considered to be drought years under the definition employed if the total rainfall for the whole period is more than 80% of the LTA. Hence, the probability estimates using this definition of drought are likely to be lower than the "true" value. On the other hand, the government may declare drought in response to political pressure even if the effect is mild and/or is more localized. Thus, the probability estimates based on government declarations of drought are likely to be on the higher side. The probability estimates derived from government-declared drought events are, in fact, 24–42% higher than those derived from the rainfall-based definition.

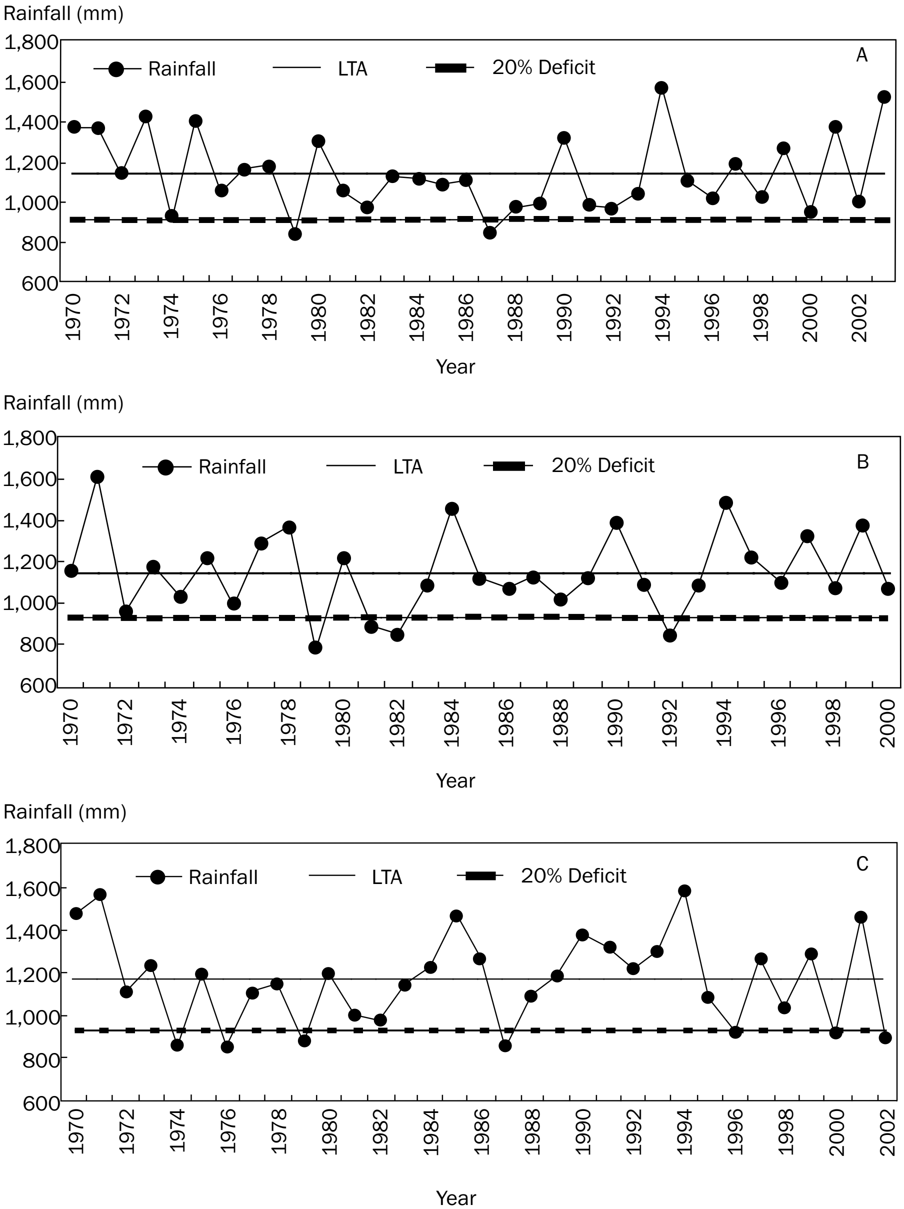



**Fig. 4.6. Actual and long-term average (LTA) monsoon rainfall in (A) Chattisgarh, 1970-2003; (B) Jharkhand, 1970-2000; and (C) Orissa, 1970-2002.**

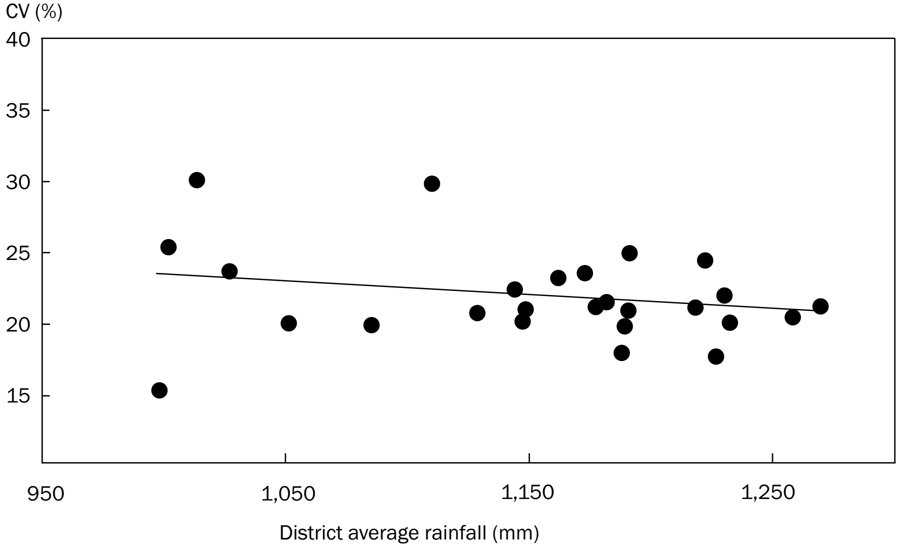



**Fig. 4.7. District-level plot of coefficient of variation of monsoon rainfall with average rainfall, eastern India, 1970-2002.**

How often does a crop suffer from drought in the early season and also in the late season in the same year? This question can be answered by examining the joint probabilities. Both early and late droughts occur in the same year in various districts, but not necessarily in all districts in the same year. Hence, the joint probabilities at the state level are lower than for individual districts. The spatial pattern of joint probabilities indicates that the probability of both early- and late-season drought occurring in the same year is more than 9% in over 80% of the districts.

The frequency of covariate drought events is estimated by considering droughts that cover at least 50% of the districts within a state. The probability of spatial covariation of early-season, late-season, and monsoon-season drought is 32–35%, 43–58%, and 20–40%, respectively. Thus, the drought events in eastern India are spatially highly covariate. Droughts are generally not limited to a few districts but tend to be widespread in the region. This is especially true for terminal drought.

Probability estimates by severity of drought indicate that, for all three states, early-season drought of moderate or severe intensity occurs with almost equal probability. Virtually no incidence of "calamitous" drought occurs in the early season. On the other hand, the probability distribution shifts toward "severe" and "calamitous" drought for the late season. Approximately two-thirds of the late-season droughts tend to be severe or calamitous.

Overall, droughts are more frequent, more covariate, and more severe during the late season than during the early season. Given a high sensitivity of rice yield to drought during this growth stage, late-season drought is likely to have a greater impact on production.

**Table 4.9. Drought years identified based on monsoon rainfall deficit and government declaration, eastern India, 1970-2002.**

| State | Drought year | Basis of drought year identification | |
|---|---|---|---|
| | | Rainfall-based[a] | Government-declared[b] |
| Chattisgarh[c] | 1974 | x | x |
| | 1976 | | x |
| | 1979 | x | x |
| | 1987 | x | x |
| | 1998 | | x |
| | 2000 | x | x |
| | 2002 | x | x |
| Jharkhand | 1972 | | x |
| | 1979 | x | x |
| | 1981 | x | x |
| | 1982 | x | x |
| | 1991 | | x |
| | 1992 | x | x |
| | 2000 | x | x |
| | 2002 | x | x |
| Orissa | 1974 | x | x |
| | 1976 | x | x |
| | 1979 | x | x |
| | 1982 | | x |
| | 1984 | | x |
| | 1987 | x | x |
| | 1996 | x | x |
| | 1998 | | x |
| | 2000 | x | x |
| | 2002 | x | x |

[a]Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005). [b]Katiyar (1993), Nagarajan (2003), Directorate of Agriculture and Food Production, Orissa (2004). [c]Rainfall-based drought year for Chattisgarh is obtained using rainfall data for 1970-2003.

**Table 4.10. Marginal probability of drought in different seasons, eastern India, 1970-2003.[a]**

| State | Early | Mid | Late | Monsoon |
|---|---|---|---|---|
| Chattisgarh | 0.21 | 0.09 | 0.38 | 0.15 |
| Jharkhand | 0.26 | 0.23 | 0.32 | 0.18 |
| Orissa | 0.21 | 0.18 | 0.33 | 0.21 |

[a]Drought year is defined as that year with rainfall deficit of >20% from long-term average.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

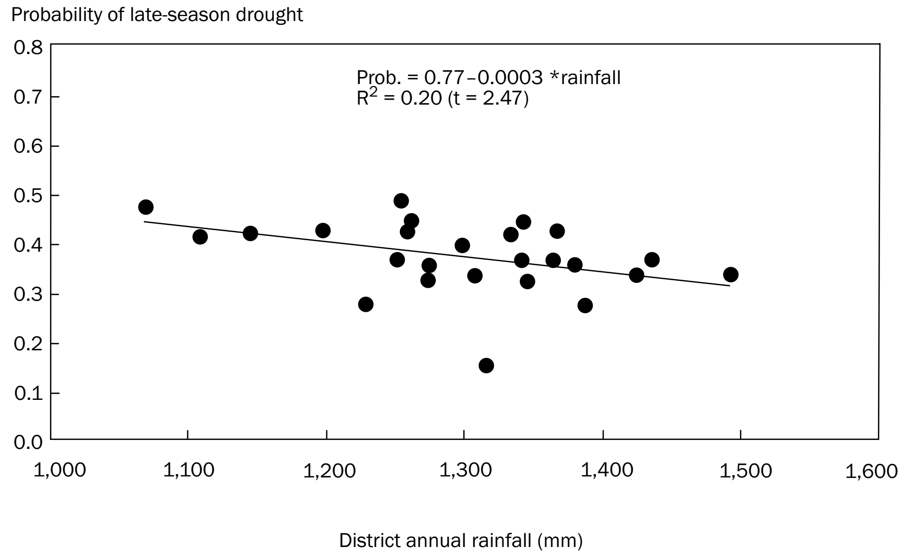



**Fig. 4.8. Scatter plot of probability of late-season drought with average annual rainfall, eastern India, 1970-2002.**

## 3.3 Aggregate impact of drought

The observed temporal fluctuations in yield and area are the results of many stochastic factors, including drought. The size of the temporal fluctuations can hence provide some indications of the likely overall magnitude of the effect of drought. Here, CVs, estimated using linearly de-trended time-series data on rice area, yield, and production, are used for an initial analysis.

Using the CV as a measure of instability, rice area, yield, and production instability for three states from 1970 to 2003 are 1–5%, 18–21%, and 19–22%, respectively. This is a measure of instability resulting from all sources of variation, not just drought. However, given that these states are chronically drought-prone, much of this variation originates from drought. Yield instability is indeed quite high and accounts for a large proportion of production instability. Area instability is relatively low in all three states. Chattisgarh has the lowest area instability but the highest yield instability among the three states.

Juxtaposition of time-series data on rainfall and yield can give some indications of the correlation between drought events as defined and yield. The results indicate high correlation between these two variables for all three states (Fig. 4.9A, 4.9B, and 4.9C). The dips in the rainfall series mirror the dips in the yield series in most cases for each state.

To investigate the impact of drought, the elasticity of rice area, yield, and production with respect to rainfall is estimated using the methodology described in Section

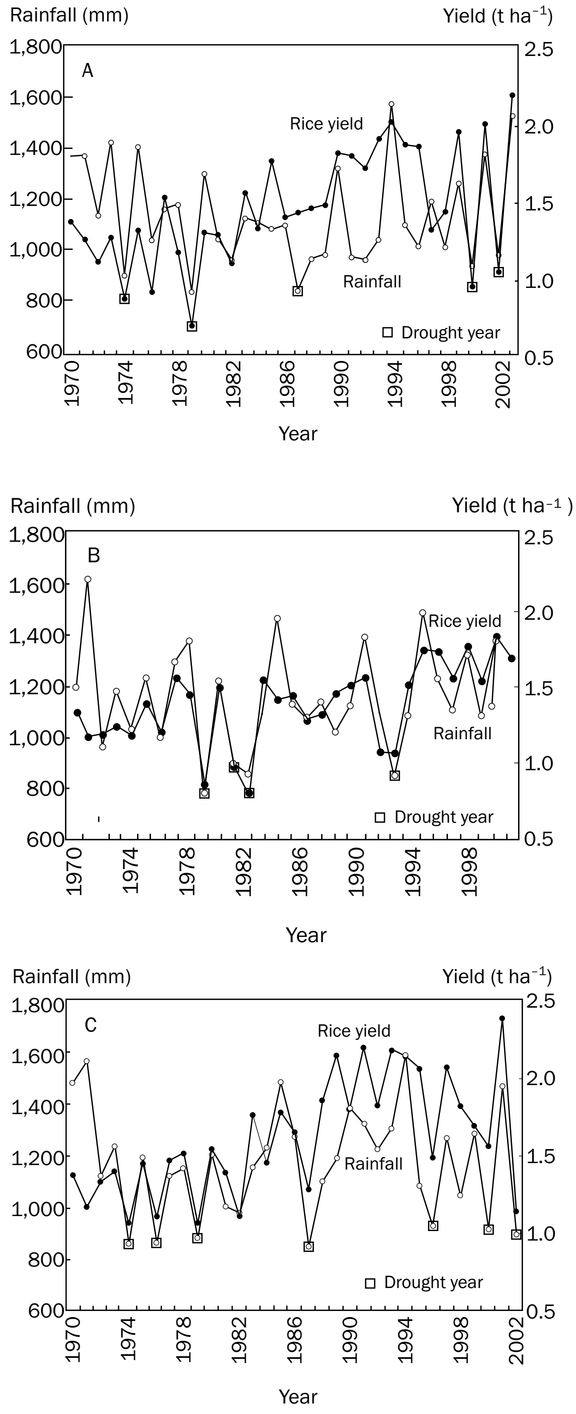



**Fig. 4.9. Rice yield and monsoon rainfall (June-October) correlation in (A) Chattisgarh, 1970-2003; (B) Jharkhand, 1970-2000; and (C) Orissa, 1970-2002.**

**Table 4.11. Rainfall elasticity of rough rice area, yield, and production, eastern India, 1970-2002.[a]**

| States/districts | Area | Yield | Production |
|---|---|---|---|
| Chattisgarh | 0.03 | 0.54*** | 0.57*** |
| Bastar | 0.02 | 0.07 | 0.10 |
| Bilaspur | 0.02 | -0.05 | -0.03** |
| Durg | 0.04** | 0.19 | 0.23* |
| Raigarh | 0.00 | 0.30 ** | 0.29*** |
| Raipur | 0.01 | 0.38 ** | 0.39*** |
| Rajnandgaon | 0.00 | 0.44*** | 0.44*** |
| Surguja | 0.01 | 0.31 ** | 0.32*** |
| Jharkhand | 0.14*** | 0.42*** | 0.56*** |
| Dhanbad | 0.28*** | 0.46*** | 0.75*** |
| Hazaribagh | 0.17*** | 0.53*** | 0.69*** |
| Palamau | 0.27*** | 0.53*** | 0.80*** |
| Ranchi | 0.09*** | 0.48*** | 0.57*** |
| Santhal Parganas | 0.14*** | 0.32 ** | 0.46*** |
| Singhbhum | 0.04 | 0.49*** | 0.53*** |
| Orissa | 0.04 | 0.47*** | 0.52*** |
| Balasore | 0.08** | 0.07 | 0.14** |
| Bolangir | 0.06*** | 0.46 ** | 0.51*** |
| Cuttack | 0.05 | 0.15 | 0.20 |
| Dhenkanal | -0.07 | 0.74*** | 0.67*** |
| Ganjam | 0.05 | 0.50 ** | 0.55*** |
| Kalahandi | 0.07** | 0.75*** | 0.82*** |
| Keonjhar | -0.05 | 0.47*** | 0.42*** |
| Koraput | 0.06 | 0.71*** | 0.77*** |
| Mayurbhanj | 0.02 | 0.18 | 0.21*** |
| Phulbani | 0.18*** | 0.55*** | 0.74*** |
| Puri | 0.05 | 0.20 | 0.25*** |
| Sambalpur | 0.06* | 0.45*** | 0.51*** |
| Sundargarh | 0.01 | 0.48*** | 0.49*** |

[a]Area, yield, and production elasticities are estimated using early-season (Jun-Jul), late-season (Aug-Oct), and monsoon-season (Jun-Oct) rainfall, respectively. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Statistical significance of elasticity was tested using SHAZAM software (SHAZAM 2004). Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

2 (see Chapter 3 for details). The estimated elasticity coefficients[3] for the districts and states using district-level and state-level time-series data over the period 1970-2002 are presented in Table 4.11. The overall production elasticity for all three states is over 0.5. For example, rainfall elasticity of rice production for Jharkhand is 0.56. This implies that a drop in rainfall by 10% will result in a production drop relative

[3]In India, rice is planted during June and July and harvested in October. Thus, rainfall during June-July is important for rice planting while rainfall in August-October affects rice yield. Hence, rice area, yield, and production responses are evaluated using different period rainfalls—June-July for area, August-October for yield, and June-October for production.

to the “normal” level by 5.6%. Since drought here is defined as at least a 20% drop in rainfall, the corresponding reduction in output of rice would be 11%. The overall area elasticity is significant only in Jharkhand but yield elasticity is significant for all three states. When the state-level production elasticity is decomposed into its area and yield components, it can be seen that the drop in area during drought years accounts for about 5–25% of the drop in production. Thus, the overwhelming effect of drought is a reduction in yield per unit area. Nevertheless, the area response is not trivial, especially in Jharkhand.

The spatial distribution of area and yield elasticities with respect to rainfall in all three states indicates that the area elasticity is significant in 42% of the districts only, whereas yield elasticity is significant in 73% of the districts. Moreover, the coefficients of area elasticities are smaller that those of the yield elasticities. It is to be noted that area elasticities are significant mainly in inland districts. The overall picture is that of a generally low area response but high yield response over a larger area.

The effect of drought on rice and nonrice crop production was also examined using the drought dummy variables as described in Section 2 (see Chapter 3 for details). Both definitions of drought years (i.e., using rainfall-based indicators and the government declaration of drought) were used to estimate production losses. The estimated dummy variable models for rice and major nonrice crops (pulses and oilseeds) are presented in Tables 4.12 and 4.13. The statistically significant F-values for both types of models for all crops in all states except pulses in Jharkhand and relatively high $R^2$ values indicate that the data fit the models well. The coefficient of the drought dummy variable provides a measure of the average production losses during drought years. For example, the marginal coefficient of the drought dummy for rice production in Chattisgarh (Table 4.12) implies that the average rice production loss in Chattisgarh in drought years is 2 million tons. Only statistically significant drought dummy coefficients are used to estimate the value of production loss due to drought.

The estimated average production loss during drought years using both approaches is close, with the value of production loss of rice for the three states varying from 34% to 41% of the average value of production (Table 4.14). For each state, the rainfall deficit-based indicator of a drought year produced a slightly higher loss estimate than that based on the government-declared drought. In absolute terms, the estimated average value of rice production loss for the combined three states during drought years approximates US$680 million. This is a substantial loss indeed.

The above estimate is the average value of losses for drought years only. As drought does not occur every year, this estimate needs to be multiplied by the probability of drought to arrive at the average annual loss. For this, the state-level losses that are statistically significant are weighted by the respective drought probabilities. The expected annual loss in rice production for three states combined is obtained by summing up the probability-weighted rice production loss across states.

The loss estimates across states range from 6% to 10% of the annual value of rice output (Table 4.15). For each state, the ratio of loss to average value of production differs by 2–3 percentage points depending on whether the probability estimates

**Table 4.12. Ordinary least square estimates of effect of rainfall-based drought dummy on production of rice, pulses, and oilseeds, eastern India, 1970-2002.[a]**

| States | Parameters | Rice | Pulses | Oilseeds |
|---|---|---|---|---|
| Chattisgarh | | | | |
| | Intercept | 3,315.5 | 341.3 | 62.2 |
| | Time | 119.0*** | 4.6** | 2.9*** |
| | Drought dummy | –2,055.4*** | –69.2 | 8.4 |
| | F-value | 33.6*** | 3.3** | 10.8*** |
| | Adjusted $R^2$ | 0.67 | 0.12 | 0.38 |
| | Observations (no.) | 33 | 33 | 33 |
| Jharkhand | | | | |
| | Intercept | 2,121.3 | 128.6 | 43.6 |
| | Time | 7.4 | –0.1 | –0.3 * |
| | Drought dummy | –872.3*** | –25.0** | –10.2 ** |
| | F-value | 19.7*** | 2.3 | 4.6 ** |
| | Adjusted $R^2$ | 0.56 | 0.08 | 0.20 |
| | Observations (no.) | 30 | 30 | 30 |
| Orissa | | | | |
| | Intercept | 5,719.2 | 714.6 | 390.3 |
| | Time | 114.3*** | 9.5** | 12.8*** |
| | Drought dummy | –2,493.6*** | –328.5*** | –226.8*** |
| | F-value | 31.7*** | 7.4*** | 9.7*** |
| | Adjusted $R^2$ | 0.66 | 0.29 | 0.35 |
| | Observations (no.) | 33 | 33 | 33 |

[a]***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The dependent variable is production in 000 t. The coefficient of drought dummy provides an estimate of production losses during drought years. A drought year is defined as that year with a monsoon-season rainfall (June-October) deficit of >20% from long-term average.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

based on a drought declaration or on rainfall are used. The difference is mainly due to the higher frequency of drought events if the government declaration is used as the basis for estimating the probability of drought. Irrespective of the probability estimates used, the expected proportionate loss is highest for Orissa and lowest for Chattisgarh. The total annual loss in rice production for the three states combined is 1.0 to 1.3 million tons, which is about 7–9% of the mean output. Using the average rough rice price of $125 per ton, the value of annual production loss estimated this way is $125 to $175 million.

The losses of nonrice crops (mainly oilseeds and pulses) during drought years are estimated at 22% and 41% of the annual value of nonrice crops in Jharkhand and Orissa, respectively. The relatively higher proportionate loss in Orissa is due to relatively more area under nonrice crops in Orissa than in the other two states. The effect of drought on nonrice crops in Chattisgarh is found to be almost nonexistent. The addition of losses in nonrice crops alters the total annual estimates of loss from

**Table 4.13. Ordinary least square estimates of effect of government-declared drought dummy on production of rice, pulses, and oilseeds, eastern India, 1970-2002.[a]**

| State | Parameters | Rice | Pulses | Oilseeds |
|---|---|---|---|---|
| Chattisgarh | | | | |
| | Intercept | 3,401.7 | 348.4 | 63.5 |
| | Time | 119.9*** | 4.8** | 3.0*** |
| | Drought dummy | –1,942.8*** | –97.0** | –4.5 |
| | F-value | 40.1*** | 5.1** | 10.6*** |
| | Adjusted $R^2$ | 0.71 | 0.20 | 0.38 |
| | Observations (no.) | 33 | 33 | 33 |
| Jharkhand | | | | |
| | Intercept | 2,197.3 | 129.5 | 44.4 |
| | Time | 5.4 | –0.2 | –0.3 * |
| | Drought dummy | –804.4*** | –18.3* | –9.3** |
| | F-value | 29.7*** | 1.6 | 5.2** |
| | Adjusted $R^2$ | 0.66 | 0.04 | 0.23 |
| | Observations (no.) | 30 | 30 | 30 |
| Orissa | | | | |
| | Intercept | 5,852.7 | 722.0 | 394.1 |
| | Time | 119.1*** | 9.8** | 13.0*** |
| | Drought dummy | –2,452.9*** | –272.3** | –181.5** |
| | F-value | 45.8*** | 6.3** | 8.5*** |
| | Adjusted $R^2$ | 0.74 | 0.25 | 0.32 |
| | Observations (no.) | 33 | 33 | 33 |

[a]***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The dependent variable is production in 000 t. The coefficient of drought dummy provides an estimate of production losses during drought years. A year is considered as a drought year when it is declared by the government as a drought year.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

drought by only a small fraction of a percentage point. In absolute amounts, the total annual loss for the three states combined is estimated at $162 million. Thus, the total estimated loss is 7% of the average value of rice and nonrice production. Overall, the analysis shows that drought resulted in a production loss of 7–9% of the average value of rice output in eastern India.

## 4. Farm-level analysis

The major characteristics of rice production systems, household income structure, and farm-level impacts of drought are discussed in this section. The drought impacts are analyzed by comparing farming practices, crop yields, and net returns between "normal" and "drought" years. The results and discussions are based on farm survey data.

**Table 4.14. Average value of crop production losses during drought years using a rainfall-based and government-declared drought dummy, eastern India, 1970-2002.[a]**

| States and crops | Average value of production (million US$) | Rainfall-based drought: Value of production loss during drought year (million US$) | Rainfall-based drought: Ratio of loss to average value of production (%) | Government-declared drought: Value of production loss during drought year (million US$) | Government-declared drought: Ratio of loss to average value of production (%) |
|---|---|---|---|---|---|
| Chattisgarh | | | | | |
| Rice | 628 | 257 | 41 | 243 | 39 |
| Nonrice | 157 | 0 | 0 | 29 | 18 |
| Total | 785 | 257 | 33 | 272 | 35 |
| Jharkhand | | | | | |
| Rice | 265 | 109 | 41 | 101 | 38 |
| Nonrice | 48 | 11 | 22 | 8 | 17 |
| Total | 313 | 120 | 38 | 109 | 35 |
| Orissa | | | | | |
| Rice | 892 | 312 | 35 | 307 | 34 |
| Nonrice | 410 | 167 | 41 | 136 | 33 |
| Total | 1,302 | 478 | 37 | 443 | 34 |
| Eastern India | | | | | |
| Rice | 1,785 | 678 | 38 | 651 | 36 |
| Nonrice | 615 | 178 | 29 | 173 | 28 |
| Total | 2,400 | 856 | 36 | 824 | 34 |

[a]Only important crops (rice, pulses, and oilseeds) with significant drought dummy coefficients were used to estimate the total production losses. Prices used to compute the value of production losses for rice and nonrice are $125 $t^{-1}$ and $300 $t^{-1}$, respectively.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

**Table 4.15. Average annual value of crop production losses due to drought using rainfall-based and government-declared drought years, eastern India, 1970-2002.[a]**

| States and crops | Rainfall-based drought: Drought prob. (P) | Value of production loss per year (million US$) | Ratio of loss to average value of production (%) | Government-declared drought: Drought prob. (P) | Value of production loss per year (million US$) | Ratio of loss to average value of production (%) |
|---|---|---|---|---|---|---|
| Chattisgarh | | | | | | |
| Rice | 0.15 | 39 | 6 | 0.21 | 51 | 8 |
| Nonrice | 0.15 | 0 | 0 | 0.21 | 6 | 4 |
| Total | 0.15 | 39 | 5 | 0.21 | 57 | 7 |
| Jharkhand | | | | | | |
| Rice | 0.18 | 20 | 8 | 0.24 | 24 | 9 |
| Nonrice | 0.18 | 2 | 4 | 0.24 | 2 | 4 |
| Total | 0.18 | 22 | 7 | 0.24 | 26 | 8 |
| Orissa | | | | | | |
| Rice | 0.21 | 66 | 7 | 0.30 | 92 | 10 |
| Nonrice | 0.21 | 35 | 9 | 0.30 | 41 | 10 |
| Total | 0.21 | 101 | 8 | 0.30 | 133 | 10 |
| Eastern India | | | | | | |
| Rice | – | 125 | 7 | – | 167 | 9 |
| Nonrice | – | 37 | 6 | – | 49 | 8 |
| Total | – | 162 | 7 | – | 216 | 9 |

[a]Only important crops (rice, pulses, and oilseeds) with significant drought dummy coefficients were used to estimate annual crop production losses.
Data sources: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).

## 4.1 Major characteristics of rice production systems and the household economy

The average farm size of the sample farms is highest at 3.1 ha in Chattisgarh and lowest in Orissa at 1.6 ha (Table 4.16). Although this indicates an overall lower population pressure in Chattisgarh, the distribution of land among the sample households in Chattisgarh is less equitable, with more than 50% of land being owned by only 25% of the households. This observation is also supported by a higher Gini coefficient associated with land distribution.

Land quality is an important determinant of farm productivity. In the context of rice farms, land quality can be considered in terms of land types such as upland, medium land, and lowland. For rice production, field hydrology generally becomes less

**Table 4.16. Households' average farm size (ha) and Gini ratio of landholding, eastern India.**

| State | Farm size category[a] | | | | | Gini ratio of landholding |
|---|---|---|---|---|---|---|
| | Marginal | Small | Medium | Large | All | |
| Chattisgarh | 0.74 | 1.44 | 2.82 | 7.05 | 3.13 | 0.37 |
| Jharkhand | 0.72 | 1.43 | 2.74 | 5.30 | 1.88 | 0.36 |
| Orissa | 0.64 | 1.37 | 2.58 | 6.10 | 1.55 | 0.07 |

[a]Farm size class is defined as marginal (<1 ha), small (1–1.99 ha), medium (2–3.99 ha), and large (≥4 ha).

**Table 4.17. Cropwise percentage share of gross cropped area among sample households in normal year, eastern India.**

| Crop | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Rice | 77 | 54 | 44 |
| Wheat | 4 | 4 | 3 |
| Maize | 0 | 10 | 4 |
| Coarse cereals[a] | 2 | 2 | 7 |
| Pulse | 14 | 21 | 26 |
| Oilseed | 2 | 6 | 10 |
| Other | 1 | 3 | 6 |

[a]Coarse cereals include jowar, bajra, ragi, barley, and minor millets.

favorable as the toposequence moves up from lowland to upland. The relative share of these three land types is hence an important descriptor of the overall land quality of a farm.[4] The distributions of these three land types in Jharkhand and Orissa are almost identical. Close to 50% of the land is upland, with the balance split almost equally into medium land and lowland. This distribution is invariant across farm size categories. The sample households of Chattisgarh are in contrast in terms of both average farm size and the distribution of different types of land. Medium land and lowland account for over 80% of the total farm area in Chattisgarh.

Rice is the main crop in all states, accounting for the lion's share of the gross cropped area. The share of rice in gross cropped area is highest in Chattisgarh (77%) and lowest in Orissa (44%) (Table 4.17). Thus, cropping systems in Jharkhand and Orissa are more diversified than in Chattisgarh. Pulses and oilseeds are the two other crops that account for a relatively large share of gross cropped area. Other crops are of relatively minor importance. Rice is the main kharif[5]-season crop in all three states.

[4]We have used the farmers' classification of land into upland, medium land, and lowland. The farmer-based classification may have some problems when comparing land types across locations as what is considered upland in one location may be considered medium land in another. Similar difficulties may arise with medium land and lowland. The analysis of land types conducted here is subject to this caveat. However, we expect the margin of error to be small since farmers in all locations had similar definitions of land type based on field hydrology.

[5]Kharif and rabi are the two major cropping seasons in India. The kharif (or rainy) season, which is a period from June to October, is the main cropping season and coincides with the southwest monsoon. The rabi (or postrainy) season is a period from November to March. Only a small proportion of land is cultivated in the rabi season.

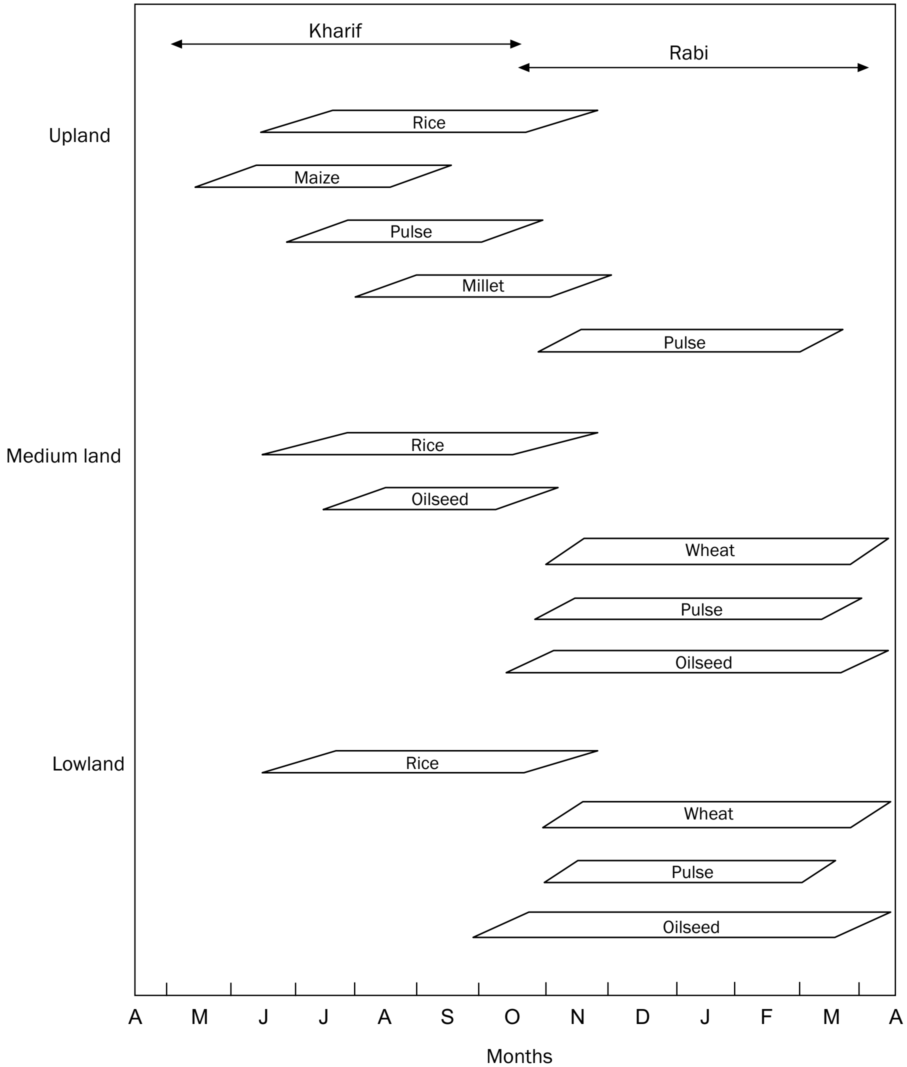



**Fig. 4.10. Land type and cropping calendar, eastern India.**

Pulses and oilseeds are grown in both kharif and rabi seasons, although the area under oilseeds in rabi is generally more than in kharif (Fig. 4.10).

The cropping intensity index, measured as the ratio of gross cropped area to net sown area, indicates the intensity of land use. The overall cropping intensity ranged from 114% to 132%. The low cropping intensity is mainly due to rainfed production systems and heavy dependence on rainfall. The variation is mainly due to the differences in cultivated land during the rabi season. In terms of land type, cropping intensity ranges from 97% to 104% in upland and 125% to 186% in lowland. Cropping intensity

**Table 4.18. Average rough rice yield (t ha$^{-1}$) among sample households, by land type, eastern India.**

| Land type | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Upland | 1.55 | 0.70 | 0.81 |
| Midland | 1.42 | 1.43 | 1.20 |
| Lowland | 1.47 | 2.26 | 1.78 |
| All land | 1.44 | 1.54 | 1.37 |

**Table 4.19. Average gross income (US$) per household in normal year, eastern India.[a]**

| Income source | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Agriculture | 670 | 310 | 420 |
| Nonagriculture | 180 | 190 | 200 |
| Total | 850 | 500 | 620 |

[a]Exchange rate used is US$1 = Indian rupee 43.70.

generally decreases with the move up the toposequence. Overall, the intensity of land use is relatively low in all three states.

Average rice yield is relatively low[6] for all three states and varies within the narrow range of 1.37 to 1.54 t ha$^{-1}$ (Table 4.18). With the exception of uplands in Chattisgarh, yield decreases with the move up the toposequence. In Jharkhand and Orissa, rice yield in lowlands is 2–3 times higher than in uplands and 50–60% higher than in medium lands. Variations in water-holding capacity of soil due to different texture and slope, and other soil quality characteristics, contribute to this yield variation across the toposequence.

The adoption of modern varieties (MV) is lowest at 26% of the area in Jharkhand and highest in Orissa at 74%. In terms of land type, the MV adoption rate ranges from 16% to 58% of the area in upland and 36% to 85% of the area in lowland. The adoption rate increases as one moves down the toposequence from upland to lowland. Although the causes for this differential pattern of adoption are not investigated in this study, land type has been found to be an important determinant in a related study (Pandey et al 2004).

The average household income in Jharkhand and Orissa is similar, but it is substantially higher in Chattisgarh (Table 4.19). The relatively larger average farm size in Chattisgarh partly accounts for this difference. Agricultural income in Chattisgarh is substantially higher relative to the other two states. The income structure in all three states is similar, as indicated by the share of agricultural and nonagricultural income (Table 4.20). Overall, the share of rice income increases with an increase in farm size,

[6]The low rice productivity of sample households, even lower than the state average, is mainly due to the selection of highly drought-prone areas for the farm-level study.

**Table 4.20. Percentage share in average annual gross income per household during normal year, by farm size category, eastern India.**

| Income source | Farm size category | | | | |
|---|---|---|---|---|---|
| | Marginal | Small | Medium | Large | All |
| **Chattisgarh** | | | | | |
| **Agriculture** | **65** | **73** | **77** | **84** | **79** |
| Rice | 26 | 40 | 53 | 56 | 51 |
| Nonrice crop | 7 | 12 | 16 | 27 | 20 |
| Farm labor | 29 | 19 | 7 | 1 | 7 |
| Small animals[a] | 3 | 2 | 1 | 0 | 1 |
| Forest produce | 0 | 0 | 0 | 0 | 0 |
| **Nonagriculture** | **35** | **27** | **23** | **16** | **21** |
| Hired labor | 32 | 15 | 5 | 2 | 6 |
| Services | 0 | 6 | 13 | 11 | 11 |
| Business | 0 | 0 | 0 | 0 | 0 |
| Self-employment | 0 | 4 | 4 | 3 | 3 |
| Others[b] | 3 | 2 | 1 | 0 | 1 |
| **Total** | **100** | **100** | **100** | **100** | **100** |
| **Jharkhand** | | | | | |
| **Agriculture** | **60** | **59** | **65** | **63** | **62** |
| Rice | 21 | 27 | 35 | 41 | 30 |
| Nonrice crop | 12 | 11 | 14 | 14 | 12 |
| Farm labor | 18 | 13 | 9 | 3 | 12 |
| Small animals[a] | 3 | 2 | 2 | 1 | 2 |
| Forest produce | 6 | 6 | 5 | 4 | 6 |
| **Nonagriculture** | **40** | **41** | **35** | **37** | **38** |
| Hired labor | 34 | 27 | 17 | 15 | 24 |
| Services | 3 | 10 | 18 | 20 | 12 |
| Business | 3 | 4 | 0 | 2 | 2 |
| Self-employment | 0 | 0 | 0 | 0 | 0 |
| Others[b] | 0 | 0 | 0 | 0 | 0 |
| **Total** | **100** | **100** | **100** | **100** | **100** |
| **Orissa** | | | | | |
| **Agriculture** | **59** | **65** | **74** | **74** | **67** |
| Rice | 14 | 19 | 27 | 31 | 21 |
| Nonrice crop | 14 | 27 | 35 | 40 | 27 |
| Farm labor | 26 | 14 | 7 | 1 | 14 |
| Small animals[a] | 5 | 5 | 4 | 2 | 5 |
| Forest produce | 0 | 0 | 1 | 0 | 0 |
| **Nonagriculture** | **41** | **35** | **26** | **26** | **33** |
| Hired labor | 31 | 21 | 8 | 1 | 18 |
| Services | 7 | 8 | 10 | 15 | 10 |
| Business | 3 | 5 | 8 | 8 | 5 |
| Self-employment | 0 | 0 | 0 | 0 | 0 |
| Others[b] | 0 | 1 | 0 | 2 | 0 |
| **Total** | **100** | **100** | **100** | **100** | **100** |

[a]Small animals include goats, sheep, chickens, ducks, calves, kids, and animal produce such as milk, ghee, eggs, etc. [b]Others include old-age pension, small petty business, and small artisan work.

indicating that rice production is relatively more important to large farmers than to small and marginal ones. Similarly, the share of nonrice crops in total income also increases with farm size. Thus, the income of larger farm-size categories is generally based more on crop production.

Small and marginal farmers whose land base is small rely relatively more on agricultural labor earning and livestock production, which are not land-intensive activities. The share of income from these activities is much higher for small and marginal farmers than for medium and large ones. Thus, there is a clear dichotomy in the income strategies of these two groups of farmers (large and medium in one group versus small and marginal in the other). The share of nonfarm income decreased with an increase in farm size. The relative share of income from regular employment services increased, whereas that from hired labor decreased with an increase in farm size. Small and marginal farmers tend to engage in low-paying wage-earning activities, whereas larger farmers, who are more able to invest in education, enter into higher-paying regular employment.

In summary, the income structure of the survey area is typical of that of a rural economy where agriculture is the major economic activity and the nonfarm sector is in its early stages of development (Hossain et al 2000). Small and marginal farmers whose land base is small derive relatively less income from rice and other crops, but are more dependent on wage employment in both the farm and nonfarm sectors. The share of rice production in their total income is relatively low (14–40%). Wage employment in the farm and nonfarm sector accounts for 34–61% of their total income. On the other hand, medium and large farmers obtain a relatively higher share of their income from crop production. The share of rice in their income is much higher (27–56%). They also derive relatively more income from salaried employment.

## 4.2 Farm- and household-level impact of drought

One of the major consequences of drought is a substantial reduction in gross cropped area. The loss in gross cropped area is estimated to be 27%, 53%, and 33% in Chattisgarh, Jharkhand, and Orissa, respectively. The loss in gross cropped area occurred not only in the kharif season as normally expected, but also in the rabi and summer seasons. The area under pulses and oilseeds, which are important crops in both the kharif and rabi seasons, also contracted substantially during drought years. For example, the rabi-season cropped area contracted by 83%, 68%, and 45% in Chattisgarh, Jharkhand, and Orissa, respectively, relative to the normal year. Thus, reliance on rabi crops when kharif crops are damaged does not seem to be an effective drought-coping mechanism. The reduction in gross cropped area is also reflected in cropping intensity. The reduction in cropping intensity is 27%, 53%, and 33%, for Chattisgarh, Jharkhand, and Orissa, respectively. The reduction in cropping intensity is higher in the upper toposequence in Jharkhand but, in the other two states, there are no apparent patterns.

The losses in rice area during drought years can also be substantial. The losses in area are similar at around 40% for Jharkhand and Orissa but the estimate for Chattisgarh is lower at 25% (Table 4.21). When the losses in rice area by land type are

**Table 4.21. Percentage change in rice planted area during drought year relative to that in normal year, by land type, eastern India.**

| Land type | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Upland | –69 | –83 | –64 |
| Midland | –22 | –50 | –48 |
| Lowland | –14 | –11 | –25 |
| All land | –25 | –42 | –41 |

**Table 4.22. Percentage change in rice production during drought year relative to that of normal year, by farm-size category, eastern India.**

| Farm size category | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Marginal | –94 | –65 | –71 |
| Small | –96 | –61 | –60 |
| Medium | –96 | –59 | –59 |
| Large | –91 | –54 | –52 |
| All | –94 | –59 | –60 |

analyzed, the proportionate loss decreases as one moves down the toposequence.[7] Rice area contracted much more in uplands than in lowlands. In uplands, where the moisture-holding capacity of soils is low, farmers would need to reduce rice area in the event of inadequate rainfall much more than in medium lands and lowlands, which generally have better water-holding capacities. Households with higher proportions of uplands in their land endowment are thus likely to suffer greater losses in rice production through this area effect.

The losses in rice yield during drought years was estimated to be in the range of 25–40% in Jharkhand and Orissa but was almost 100% in Chattisgarh. It was a case of almost complete crop failure in Chattisgarh during the 2002 drought. In Jharkhand and Orissa, farmers did not suffer from total crop failure, but the yield loss in combination with a reduction in area resulted in an overall production loss of around 60%. In terms of the effect of land type, losses in both area and yield are higher in uplands and hence the total production loss is also higher in uplands than in lowlands. Thus, there is a gradient in the incidence of loss along the toposequence.

Does the relative production loss vary by farm size? For Jharkhand, the loss is almost invariant with farm-size categories (Table 4.22). For Orissa, the proportionate loss is higher for the lower farm-size category. Thus, marginal and small farmers lose their rice production proportionately more than larger farmers. Based on these

[7]These farm-level effects are higher relative to the aggregate effects for the whole district or the state presented earlier due to the averaging-out effects in aggregate data.

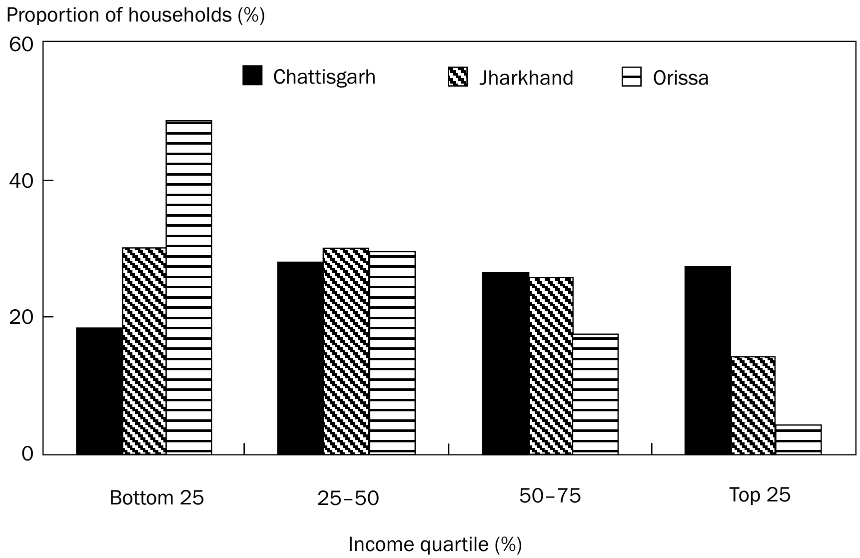



**Fig. 4.11. Distribution of households incurring over 80% of rice production losses during a drought year, by income quartile, eastern India.**

two examples, the differential effect of drought on rice production of farmers with different farm sizes appears to be nonuniform and location-specific.

The estimates of losses in rice production presented above are averages for all households. When the percentage of households suffering from various magnitudes of losses is analyzed separately, the results indicated that, for both Jharkhand and Orissa, around 30% of the households lost more than 80% of their rice output. For Chattisgarh, almost all households lost more than 80% of the output. What are the characteristics of the households that lose over 80% of their rice output? The welfare consequences could be more severe if these households are also the poorest. This is examined by assessing their landholding size and income status. For Orissa, almost half of these households belong to the bottom income quartile, while less than 10% belong to the top income quartile (Fig. 4.11). In terms of landholding, about 60% of these farmers belong to the marginal and small farm-size categories in Orissa (Fig. 4.12). Thus, the proportionate losses in rice production in Orissa are indeed higher among small and poorer farmers. Similar effects, although less pronounced, are apparent in Jharkhand, with the bottom two income quartiles accounting for over half of the households that lost more than 80% of their rice output. This highlights the regressive impact of drought.

Drought resulted in total income losses of about 24% and 26% in Jharkhand and Orissa, respectively (Table 4.23). The magnitude of loss was much higher at 58% in Chattisgarh, where the impact of drought was much more severe. Almost complete failure of the rice crop in Chattisgarh led to a much larger proportionate income loss

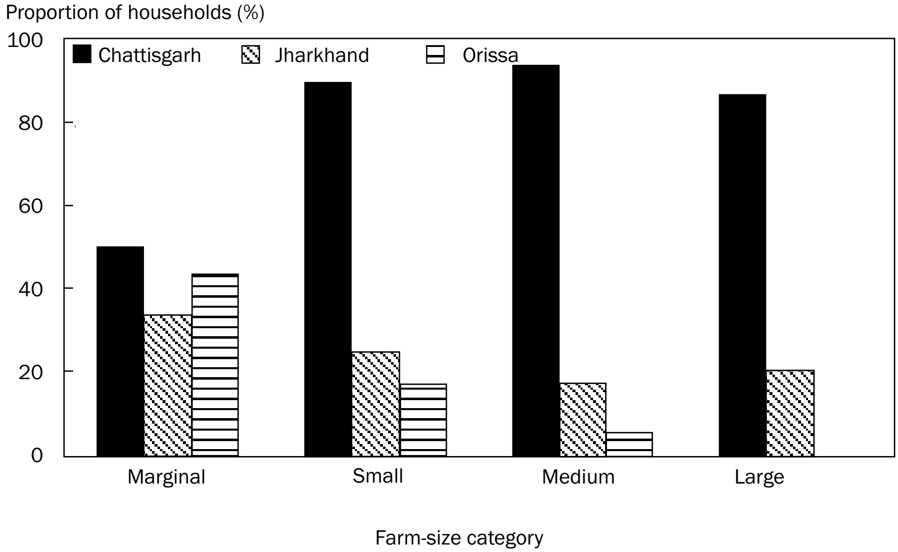



**Fig. 4.12. Distribution of households incurring over 80% of rice production losses during a drought year, by farm-size category, eastern India.**

in that state. The drop in rice income is the main factor contributing to this magnitude of loss. The loss in rice alone accounted for 44%, 75%, and 82% of the income drop in Orissa, Jharkhand, and Chattisgarh, respectively. Overall, the drop in total agricultural income in the three states was 40–80%. Earnings from farm labor also dropped substantially because of reduced labor demand. However, some small compensation resulted from increased income from livestock and forest products.

Farmers attempted to reduce the loss in agricultural income during drought years by seeking additional employment in the nonfarm sector. This mainly included employment as wage labor in the construction sector, for which farmers often migrated to distant places. The additional earning from nonfarm employment is clearly inadequate to compensate for the loss in agricultural income, thus resulting in a drop in total income of 24–58%.

Farmers relied on three main mechanisms to recoup this loss in total income: the sale of livestock, sale of other assets, and borrowing. These adjustment mechanisms helped recover only 6–13% of the loss in total income. Compared to normal years, households still ended up with a substantially lower level of income despite all these adjustments. Thus, all the different coping mechanisms farmers deployed were found to be inadequate to prevent a shortfall in income (and most likely in consumption) during drought years.

This analysis provides a general picture of the overall impact of drought on farm income. This impact is likely to differ across farm-size groups given the differences in their income strategies. Crop production loss is expected to have a smaller propor-

**Table 4.23. Average income per household (US$) in normal and drought year, eastern India.**

| Income source | CH[a] | JH | OR | CH | JH | OR | CH | JH | OR |
|---|---|---|---|---|---|---|---|---|---|
| | Normal year | | | Drought year | | | Change over normal (%) | | |
| **Total income** | **850** | **500** | **620** | **360** | **380** | **460** | **–58** | **–24** | **–26** |
| **Agriculture** | **670** | **310** | **420** | **140** | **160** | **240** | **–79** | **–48** | **–43** |
| Crop income | 600 | 210 | 300 | 90 | 70 | 160 | –85 | –67 | –47 |
| Rice | 430 | 150 | 130 | 30 | 60 | 60 | –93 | –60 | –54 |
| Nonrice | 170 | 60 | 170 | 60 | 10 | 100 | –65 | –83 | –41 |
| Farm labor | 60 | 60 | 90 | 30 | 50 | 40 | –50 | –17 | –56 |
| Small animals[b] | 10 | 10 | 30 | 20 | 10 | 30 | 100 | 0 | 0 |
| Forest produce | 0 | 30 | 0 | 0 | 30 | 10 | | 0 | 100 |
| **Nonagriculture** | **180** | **190** | **200** | **220** | **220** | **220** | **22** | **16** | **10** |
| Hired labor | 50 | 120 | 110 | 90 | 150 | 150 | 80 | 25 | 36 |
| Services | 90 | 60 | 60 | 90 | 60 | 50 | 0 | 0 | –17 |
| Business | 0 | 10 | 30 | 0 | 10 | 20 | | 0 | -33 |
| Self-employment | 30 | 0 | 0 | 30 | 0 | 0 | 0 | | |
| Others[c] | 10 | 0 | 0 | 10 | 0 | 0 | 0 | | |
| **Additional income from asset sale and/or borrowing** | **30** | **20** | **60** | **70** | **30** | **80** | **133** | **50** | **33** |
| Sale of livestock[d] | 10 | 10 | 10 | 10 | 10 | 20 | 0 | 0 | 100 |
| Sale of major assets[e] | 10 | 0 | 20 | 40 | 0 | 20 | 300 | | 0 |
| Sale of minor assets[f] | 0 | 0 | 10 | 0 | 0 | 10 | | | 0 |
| Mortgage/borrowing | 10 | 10 | 20 | 10 | 20 | 30 | 0 | 100 | 50 |
| Relief operations | 0 | 0 | 0 | 10 | 0 | 0 | 100 | | |
| **Total disposable income** | **880** | **520** | **680** | **430** | **410** | **540** | **–51** | **–21** | **–21** |

[a]CH = Chattisgarh, JH = Jharkhand, and OR = Orissa. [b]Small animals include goats, sheep, chickens, ducks, calves, kids, and animal produce such as milk, ghee, eggs, etc. [c]Others include sale of fruits, sale of fish, old-age pension, small petty business, small artisan work, and so on. [d]Livestock includes large animals such as cattle, buffalo, bullocks, and pigs. [e]Major assets include land and building. [f]Minor assets include farm implements, jewelry, and other small assets.

tionate effect on the income of smaller farm-size categories as they derive relatively less income from crop production. This is indeed the case as shown in the analysis by farm-size categories (Table 4.24). As a result of less reliance on crop production and ability to compensate partially for farm income losses through increased nonfarm labor work, the proportionate loss in total income of small and marginal farmers was less than that of the medium and large farmers. For example, the total loss in income of small and marginal farmers was 17–42%, while that of the medium and large farmers was 25–67%.

**Table 4.24. Percentage change in average annual gross income per household during drought year relative to that of normal year, by farm-size category, eastern India.**

| Income source | Marginal | Small | Medium | Large | All |
|---|---|---|---|---|---|
| ***Chattisgarh*** | | | | | |
| **Agriculture** | **–65** | **–71** | **–85** | **–81** | **–79** |
| Crop production | –80 | –84 | –89 | –83 | –85 |
| Rice | –88 | –95 | –95 | –89 | -93 |
| Nonrice | –50 | –50 | –69 | –70 | -65 |
| Farm labor | –67 | –55 | –67 | –50 | –50 |
| Small animals | 100 | 100 | 0 | 90 | 100 |
| **Nonagriculture** | **46** | **38** | **16** | **12** | **22** |
| Hired labor | 50 | 71 | 99 | 67 | 80 |
| Services | – | 0 | –10 | 0 | 0 |
| Business | – | – | – | – | – |
| Self-employment | – | 0 | –33 | 0 | 0 |
| Other income | 1 | 0 | 100 | – | 0 |
| **Total** | **–26** | **–42** | **–63** | **–67** | **–58** |
| ***Jharkhand*** | | | | | |
| **Agriculture** | **–45** | **–43** | **–45** | **–50** | **–48** |
| Crop production | –73 | –67 | –63 | –61 | –67 |
| Rice | –71 | –62 | –57 | –54 | -60 |
| Nonrice | –75 | –80 | –78 | –82 | -83 |
| Farm labor | –16 | 0 | 0 | 0 | –17 |
| Small animals | 0 | 0 | 0 | 100 | 0 |
| Others | 0 | 0 | 33 | 33 | 0 |
| **Nonagriculture** | **23** | **20** | **9** | **17** | **16** |
| Hired labor | 27 | 31 | 18 | 50 | 25 |
| Services | 0 | 0 | 0 | –6 | 0 |
| Business | 0 | 0 | – | 0 | 0 |
| Self-employment | – | – | – | – | – |
| Other income | – | – | – | – | – |
| **Total** | **–18** | **–17** | **–26** | **–25** | **–24** |
| ***Orissa*** | | | | | |
| **Agriculture** | **–44** | **–37** | **–42** | **–40** | **–43** |
| Crop production | –58 | –41 | –43 | –42 | –47 |
| Rice | –67 | –50 | –50 | –44 | -54 |
| Nonrice | –50 | –35 | –38 | –41 | -41 |
| Farm labor | –55 | –56 | –60 | –50 | –56 |
| Small animals | 48 | 33 | 1 | 0 | 0 |
| Others | 100 | 100 | 0 | 100 | 100 |
| **Nonagriculture** | **24** | **9** | **–16** | **–15** | **10** |
| Hired labor | 39 | 31 | 0 | 100 | 37 |
| Services | 0 | 0 | 0 | –4 | –17 |
| Business | –100 | –33 | –50 | –50 | –33 |
| Self-employment | – | – | – | – | – |
| Other income | – | –100 | – | 0 | – |
| **Total** | **–17** | **–21** | **– 35** | **–34** | **–26** |

**Table 4.25. Incidence of rural poverty among sample households in normal and drought year, eastern India.**

| State | National estimate of rural poverty (%)[b] | Sample estimate of poverty ratio[a] | | Increase in poverty (% points) | Number of poor people falling back into poverty (million) |
|---|---|---|---|---|---|
| | | Normal year | Drought year | | |
| Chattisgarh | 37 | 43 | 76 | 33 | 5.5 |
| Jharkhand | 44 | 57 | 69 | 12 | 2.5 |
| Orissa | 48 | 54 | 70 | 16 | 5.0 |

[a]Monthly rural poverty line income of Rs 311.34, 333.07, and 323.92 is used to define the poverty line for Chattisgarh, Jharkhand, and Orissa, respectively. [b]The poverty ratio for Chattisgarh and Jharkhand is based on values for undivided states of Madhya Pradesh and Bihar, respectively. The national poverty ratio value is based on estimates during 1999-2000.
Data source: Planning Commission (2002a).

Despite this lower proportionate loss, the welfare effect of income loss is likely to be much more severe for small and marginal farmers, who earn a much lower income even during normal years. For example, marginal farmers earned only 16–25% of the income of larger farm-size categories. The marginal and small farm-size groups are more likely to “fall back” into poverty than the other two farm-size groups. The differential impact of an income drop on the incidence of poverty is examined in the next section.

## 5. Poverty impact of drought

The effect of drought on poverty is analyzed using farm-level data on income and the poverty line for each state established by the National Planning Commission (Planning Commission 2002a). The income-based estimate of poverty derived here for normal years is reasonably close to the national estimate notwithstanding the difference in the approach used here (Table 4.25). The incidence of poverty increased substantially, especially in Chattisgarh.[8] As a result, almost 13 million additional people “fell back” into poverty in these three states. This is a substantial increase in the incidence of poverty and translates into an increase in rural poverty at the national level by 1.8 percentage points.

The effect of drought on the incidence and severity of poverty is illustrated graphically through an example from Jharkhand (Fig. 4.13). Each dot in the diagram represents the level of income per capita of each household in relation to the overall poverty line and the arrows indicate the transition to another income level during drought years. As indicated, the overall incidence of poverty increased during drought

[8]The main interest here is in the “change” in poverty resulting from drought, not in the “level” of poverty. Hence, any systematic bias uncorrelated with drought events is unlikely to influence the change in poverty appreciably.

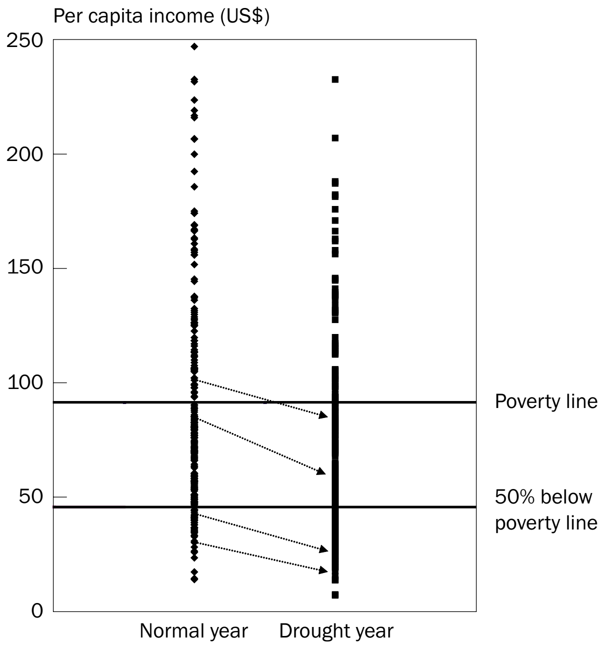



**Fig. 4.13. Effect of drought on incidence and severity of poverty, Jharkhand, India (each dot refers to a household).**

**Table 4.26. Severity of poverty among sample households in normal and drought year, eastern India.**

| Poverty index | Chattisgarh | | Jharkhand | | Orissa | |
|---|---|---|---|---|---|---|
| | NY[a] | DY | NY | DY | NY | DY |
| Head-count ratio (%) | 43 | 76 | 57 | 69 | 54 | 70 |
| Poverty gap index (%) | 11 | 39 | 19 | 30 | 15 | 22 |
| Squared poverty gap index (%) | 4 | 23 | 9 | 16 | 6 | 10 |

[a]NY = normal year, DY = drought year.

years as some people who were above the poverty line fell back into poverty. Others who were already below the poverty line got pushed further deeper into poverty.[9]

The increase in the severity of poverty is indicated by the poverty gap index and the squared poverty gap index (Table 4.26). These are estimated using the standard Foster-Greer-Thorbecke (FGT) approach (Foster et al 1984). A more intuitive picture is

[9]Some of this increase in poverty is likely to be "transient" with the affected farmers bouncing back above the poverty line fairly rapidly, but there may be an increase in the incidence of chronic poverty also.

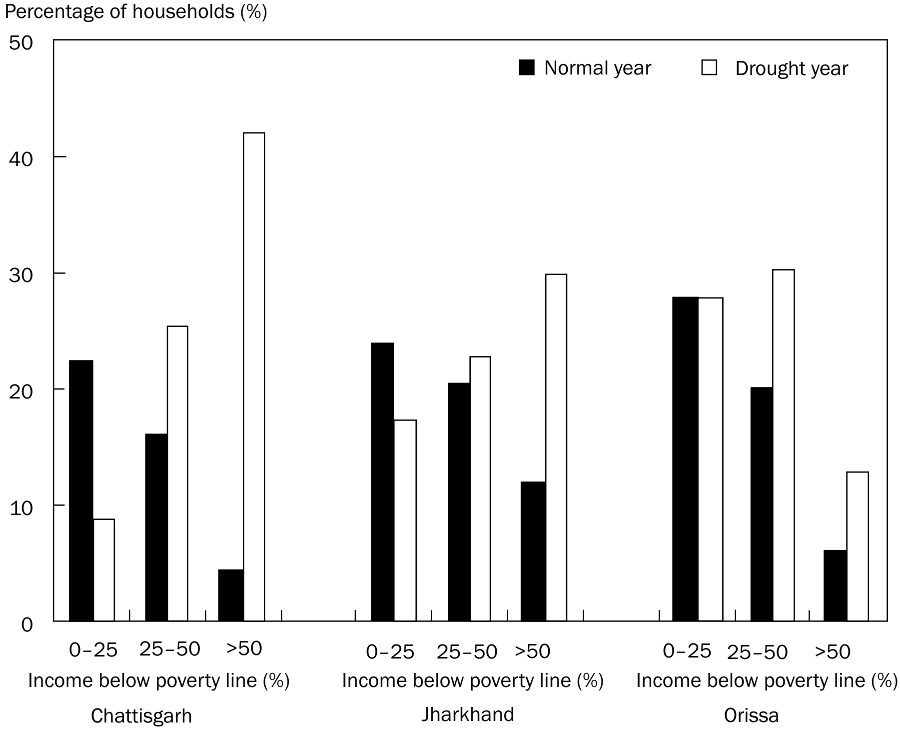



**Fig. 4.14. Frequency distribution of poverty depth in a normal and drought year, eastern India.**

provided by the distribution of poor people below the poverty line (Fig. 4.14). In each case, increases in the severity of poverty are indicated by the shift in the frequency distribution toward deeper poverty during drought years.

## 6. Household vulnerability to drought

Vulnerability refers to the capacity of a population to anticipate, cope with, and prevent a major decline in well-being, and recover rapidly from the adverse impact of shocks (Blaikie et al 1994, Downing and Bakker 2000, WB 2001, Tesliuc and Lindert 2004, Brooks et al 2005). Drought vulnerability refers to the degree to which households are susceptible to adverse effects of drought.

Vulnerability depends on a combination of factors such as income, occupation, family structure, gender, social class, caste, cultural factors, and health. Various asset-based approaches have been suggested to identify vulnerable households (Morduch 1994, Alwang et al 2001, Kamanou and Morduch 2002, Brooks et al 2005, Christiaensen and Subbarao 2005, WB 2001, 2005). These include not only physical, financial,

**Table 4.27. General characteristics of vulnerable and nonvulnerable farm households, eastern India.[a]**

| Characteristics | Household type | |
|---|---|---|
| | Vulnerable | Nonvulnerable |
| Household size (no.) | 7.1 | 5.6 |
| Age of household (HH) head (years) | 49.4 | 47.0 |
| Education of HH head (years of schooling) | 3.2 | 4.5 |
| Ratio of the number of females in the family (%) | 48 | 46 |
| Ratio of economically active individuals in the family (%) | 56 | 66 |
| Farm size (ha) | 1.6 | 3.2 |
| Cropping intensity (%) | 117 | 124 |
| Upland area (% of total land area) | 38 | 26 |
| Midland area (% of total land area) | 38 | 39 |
| Lowland area (% of total land area) | 25 | 36 |
| Household annual total income (US$)[b] | 496 | 977 |
| Farm income | 332 | 636 |
| Nonfarm income | 140 | 283 |
| Other income[c] | 24 | 58 |

[a]Vulnerability is defined in terms of income-based poverty. Households having income up to 20% above the poverty line are considered as vulnerable in this study. [b]It includes income from mortgage or sale of assets and borrowing. [c]Exchange rate used: US$1 = Rs 43.70.

and human capital but also social capital. The relationships between these assets and vulnerability are fairly complex and context dependent. Identification and quantification of these relationships will require a detailed analysis of the interacting effects of various factors, which is beyond the scope of this study. A simpler approach taken here is to preidentify vulnerable households by using an income cut-off level. Households whose incomes are below this cut-off level are considered to be "vulnerable." Analysis of the resource base and livelihood strategies of such households relative to others that are considered not vulnerable (or less vulnerable) would provide some insights into vulnerability issues. This is the approach taken here.

To link vulnerability with poverty, the cut-off level of income was set at 20% above the poverty line in this study. Households whose incomes are less than this cut-off level are defined as vulnerable.

The major characteristics of the two groups of households are summarized in Table 4.27. Vulnerable households have proportionately fewer economically active members in the family, a smaller farm size, lower cropping intensity, and a larger proportion of drought-prone upland area in their land endowments. They also have a slightly lower level of education, larger household size, and proportionately slightly more women in the family. The total household income of the vulnerable group is half that of the nonvulnerable group. Their broader income strategies, in terms of farm or nonfarm orientation, are similar, as indicated by the almost equal shares of nonfarm income in total income. However, the relative importance of various components of income

**Table 4.28. Percentage share in average annual gross income per household during normal year, by household vulnerability, eastern India.**

| Income source | Household vulnerability | |
|---|---|---|
| | Vulnerable | Nonvulnerable |
| Agriculture | 67 | 65 |
| Crop income | 46 | 57 |
| Farm labor | 16 | 5 |
| Other farm income[a] | 5 | 3 |
| Nonagriculture | 28 | 29 |
| Hired labor | 20 | 9 |
| Other nonfarm income[b] | 8 | 20 |
| Other source | 5 | 6 |
| Sale of livestock[c] | 2 | 2 |
| Sale of assets[d] | 1 | 3 |
| Mortgage/borrowing | 2 | 1 |
| Total income (US$) | 496 | 977 |

[a]Other farm income includes income from small animals, animal products, and forest produce. [b]Other nonfarm income includes income from business, services, self-employment, small petty business, old-age pension, and artisan work. [c]Livestock includes large animals such as cattle, buffalo, bullocks, and pigs. [d]Assets include cattle, buffalo, bullocks, pigs, farm implements, jewelry, and other small assets.

is different between these two groups (Table 4.28). Vulnerable households derive a smaller share of income from agricultural production but relatively more as hired labor in farm and nonfarm activities. Their income shares from self-employment, business enterprises, and government jobs are much smaller than those of the nonvulnerable groups. The difference in income strategies is the result of a smaller (and less favorable) land base of vulnerable households, and their limited ability to enter into capital and skill-intensive business enterprises and government employment.

A probit analysis was conducted to further analyze the determinants of vulnerability (Table 4.29). The likelihood ratio test is found to be significant at the 1% level, implying that the independent variables, taken together, significantly explain household vulnerability to drought. This econometric analysis supports the findings of the tabular analysis presented earlier. The variables with statistically significant effects on vulnerability are the age of the household head, proportion of females in the family, proportion of economically active population in the family, education of economically active members, farm size, proportion of upland area, and proportion

**Table 4.29. Probit estimates for the probability of household vulnerability to drought, eastern India.[a]**

| Variable | Coefficient | Standard error | Marginal probability |
|---|---|---|---|
| Constant | 1.3218 | 0.3554*** | |
| Age of household head (years) | 0.0202 | 0.0041*** | 0.0076 |
| Ratio of the number of females in the family (%) | 0.0048 | 0.0036* | 0.0018 |
| Ratio of economically active individuals in the family (%) | –0.0186 | 0.0024*** | –0.0070 |
| Average years of schooling of adult family members (16–60 years of age) | –0.0260 | 0.0174* | –0.0098 |
| Farm size (ha) | –0.3893 | 0.0379*** | –0.1468 |
| Upland area (% of total land area) | 0.0054 | 0.0024** | 0.0020 |
| Lowland area (% of total land area) | –0.0060 | 0.0021*** | –0.0022 |
| Ethnicity (dummy)[b] | –0.1323 | 0.1057 | –0.0499 |
| Jharkhand (dummy) | 0.0793 | 0.1376 | 0.0299 |
| Orissa (dummy) | –0.2234 | 0.1454* | –0.0843 |
| Likelihood ratio test (degrees of freedom = 11) | 263.77*** | | |
| Number of observations | 863 | | |

[a]***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels of probability, respectively. The dependent variable is household vulnerability to drought, defined in terms of dichotomous variable. It takes the value of 1 if the household annual total gross income is less than or equal to the level that is 20% above the poverty line and 0 otherwise. [b]Ethnicity dummy is 1 for scheduled tribe and scheduled caste and 0 for other backward caste and general caste.

of lowland area. The results indicate that households with a smaller farm size, higher proportion of upland area, and smaller proportion of lowland area are more vulnerable. Suitable safety nets targeted to such households may be needed to protect them from the adverse effects of drought.

## 7. Farmers' coping strategies

Farmers who are exposed to drought risk use different combinations of ex ante and ex post coping strategies. Over a long period of time, some of these strategies are incorporated into the nature of the farming system and are often not easily identifiable as risk-coping strategies. Others are employed only under certain risky situations and are easier to identify as responses to risk. This section presents various drought-coping strategies used by farmers in eastern India based on farm survey data.

### 7.1 Crop management adjustments

Information on adjustments in rice production practices was elicited from farmers during interviews and the results are summarized in Table 4.30. Overall, farmers do not seem to have much flexibility in making management adjustments in the rice crop

**Table 4.30. Percentage of farmers reporting adjustment in crop management practices during drought year, eastern India.**

| Adjustment in crop management practices | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| A. Crop establishment methods | | | |
| No change | 71 | 92 | 81 |
| Shifting from transplanting to broadcasting | 29 | 8 | 19 |
| B. Sowing date | | | |
| No change | 59 | 81 | 73 |
| Change | 41 | 19 | 27 |
| a. Early sowing | 19 | 0 | 0 |
| b. Late sowing | 22 | 19 | 27 |
| C. Seeding rate | | | |
| No change | 80 | 91 | 78 |
| Change | 20 | 9 | 22 |
| a. High seed rate | 13 | 5 | 22 |
| b. Low seed rate | 7 | 4 | 0 |
| D. Rice variety | | | |
| No change | 67 | 93 | 74 |
| Change | 33 | 7 | 26 |
| a. Shift to early-maturing variety | 19 | 5 | 7 |
| b. Shift to drought-resistant variety | 0 | 0 | 3 |
| c. Shift to traditional variety | 14 | 2 | 16 |
| E. Timing of inorganic fertilizer application | | | |
| No change | 74 | 89 | 86 |
| Change | 26 | 11 | 14 |
| a. No dose application | 8 | 3 | 0 |
| b. Reduce number of applications from 3–4 times to 2–3 times | 1 | 7 | 4 |
| c. Apply only at flowering time if rainfall arises | 17 | 1 | 10 |
| F. Change in amount of fertilizer | | | |
| No change | 78 | 72 | 66 |
| Change | 22 | 28 | 34 |
| a. Decrease | 22 | 28 | 34 |
| b. Increase | 0 | 0 | 0 |
| G. Perform resowing or replanting | | | |
| Not performed | 53 | 90 | 63 |
| Reasons for resowing/replanting | 47 | 10 | 37 |
| a. No germination | 9 | 8 | 11 |
| b. Poor germination | 27 | 0 | 7 |
| c. Seedlings died after germination | 11 | 2 | 19 |

*continued on next page*

**Table 4.30 continued.**

| Adjustment in crop management practices | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| H. Manual weeding | | | |
| No change | 69 | 80 | 33 |
| Change | 31 | 20 | 67 |
| a. Increase | 4 | 5 | 41 |
| b. Decrease | 27 | 15 | 26 |
| I. Herbicide application | | | |
| No change | 58 | 95 | 86 |
| Change | 42 | 5 | 14 |
| a. Increase | 1 | 0 | 3 |
| b. Decrease | 41 | 5 | 11 |
| J. Beushening | | | |
| No change | 25 | 19 | 17 |
| Unable to do | 75 | 81 | 83 |
| K. Next-season crop | | | |
| No change | – | 58 | 59 |
| Change | – | 42 | 41 |
| a. Early sowing | – | 33 | 26 |
| b. Changing of crops | – | 9 | 15 |

in response to drought. This could partly be because drought mostly occurs during the late season, by which time opportunities for crop management adjustments for reducing losses are no longer available. Other than delaying crop establishment if rains are late, replanting and resowing when suitable opportunities arise, and some reduction in fertilizer use, farmers mostly follow a standard set of practices irrespective of the occurrence of drought. The timing of drought (mostly late rather than early) and the lack of suitable technological options probably have limited the flexibility in making tactical adjustments in crop management practices to reduce losses. For example, beushening is a traditional practice that helps with weed control, but it requires enough impounded water in the field for plowing and laddering to be possible. In drought years, farmers are unable to beushen because of a lack of water. Instead of making somewhat time-intensive in-crop tactical adjustments, most farmers seem to have developed an outward-looking strategy of generating income through migration in times of distress such as drought.

Opportunities for making adjustments to the post-rainy-season crop that follows rice may exist when the rice crop is damaged or lost to drought. Farmers did make use of such opportunities by planting the second crop early where possible or by expanding the area of cash crops such as vegetables. A post-rainy-season crop that is planted early can use residual soil moisture more effectively for producing higher yield before it is depleted by evaporation. Also, early harvest of a post-rainy-season crop made possible by early planting increases household food availability earlier than normal. Although farmers make use of these opportunities for loss recovery where possible, effective use of this strategy is also somewhat limited because of low overall cropping intensity, with most of the land being left fallow during the postrainy season, and reliance on migration. In major drought years, people who have migrated to distant places would have simply not returned early enough to make use of such post-rainy-season cropping strategies to their advantage. In farmers' assessments, migration presumably provides a higher and more assured income than adjustments in post-rainy-season cropping.

## 7.2 Consumption adjustments

Since rice is a staple food, a loss in its production can be expected to result in major adjustments in the household food balance. These adjustments could range from a reduced sale of rice, reduced quantity retained as seed for the following year, an increased amount of purchased rice, a substitution of other crops for rice in the consumption basket, supplementation of food deficit by other types of food not normally consumed, and, in the worst-case scenario, a reduction in consumption.

Results from the survey indicate that all these types of adjustments are made to a varying degree. One of the major effects of production loss is reductions in the quantity sold, the quantity of seed kept for the subsequent year, and the quantity stored for future use. The quantity of rice sold during drought years decreased by 82–98% compared with normal years. This reduction in marketed quantity would obviously have a price effect in the local market, which, if not counteracted by an inflow of grain from other areas, will result in an overall reduction in consumption per capita. This price effect is likely to have a regressive impact on the welfare of poor laborers and marginal farmers, who spend a large share of their income on rice.

An increase in the purchase of rice among farmers who have adequate income to do so is another response to a production shortfall. The quantity purchased during drought years increased by 37% in Orissa, by about four times in Chattisgarh, and almost doubled in Jharkhand. Since purchases during normal years account for a small share of total consumption, even a fourfold increase in quantity purchased may not, however, be adequate to compensate for the production loss.

It may be somewhat surprising that farmers even reduced the quantity retained as seed for planting during the subsequent year. This kind of adjustment may be considered to be a rather desperate response since production during the subsequent year will almost certainly suffer when the grain meant for seed is also consumed. Survey data indicated that farmers reduce the rice stock kept for seed by about 40–93%. All of this reduction does not, however, necessarily translate into a smaller quantity of seeds available for the next cropping season as farmers normally tend to keep some extra amount of seed for precautionary reasons beyond what they actually intend to use for planting.

**Table 4.31. Household consumption behavior in normal and drought year, eastern India.**

| Household consumption behavior | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Average number of meals per day | | | |
| Normal year | 2.8 | 2.7 | 2.5 |
| Drought year | 2.2 | 2.1 | 1.8 |
| Percentage of households reducing the number of meals per day during drought year | 54 | 60 | 70 |
| Number of meals per day | | | |
| Normal year (% of households) | | | |
| 1 | 0 | 0 | 0 |
| 2 | 26 | 34 | 47 |
| 3 or more | 74 | 66 | 53 |
| Drought year (% of households) | | | |
| 1 | 10 | 11 | 33 |
| 2 | 57 | 73 | 52 |
| 3 | 33 | 16 | 15 |
| Percentage of households reducing the quantity of food per meal during drought year | 61 | 62 | 74 |
| Percentage of households consuming other food in drought year (that which is not normally eaten) | 21 | 58 | 46 |

Farmers generally store a certain quantity of food in normal years to meet any unexpected increase in demand or shortfall in production in the following year as a safety net measure. In drought years, however, farmers reduce food storage to cope with a decrease in production. The results show that the quantity of rice stored for future use in drought years decreased by 87–98% compared to the normal-year value.

Millet is important among the crops used to supplement rice in the consumption basket, especially among poorer income groups. Although millet production is also affected by drought, some expansion in area of millet as reported earlier occurs during drought years. In Orissa, the consumption of millet increased by 15% during drought years. Consumption of wheat and maize also increased somewhat.

Despite these various adjustments in cropping choices, agricultural practices, and marketing of rice (both the quantity purchased and sold), most households suffered consumption losses. They reduced both the number of meals eaten per day and the quantity consumed per meal. About 54–70% of the households reduced the number of meals per day. As a result, the average number of meals per day dropped from close to three to close to two, with 10–30% of the households reducing the frequency of food intake to one meal per day (Table 4.31). A large proportion (60–70%) of the

**Table 4.32. Percentage of households adopting other consumption adjustments in response to the occurrence of drought, eastern India.**

| Expenditure adjustments | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Expenditure on new clothes curtailed | 74 | 82 | 78 |
| Medical treatment postponed | 62 | 79 | 72 |
| Social and religious functions curtailed | 82 | 88 | 62 |
| Children's education curtailed | 52 | 68 | 57 |

households also reduced the quantity of food consumed per meal. In addition, consuming food items that are not normally eaten is a common practice to cope with a loss in food production.[10]

In addition to the reduction in the quantity of cereals consumed, the overall nutritional content of food also probably declined during drought years as households reduced the quantity of milk, meat, pulses, and vegetables that are rich in protein and vitamins. The frequency of consumption of these items also decreased substantially during drought years.

The impact of drought tends to vary according to class, age, ethnicity, and gender as these factors determine people's vulnerability to drought. Although quantitative information on this was not available, farmer interviews indicate that the impact on women and young children tends to be more than for others. This is due to their socio-cultural and economic positioning within the family and community. In a typical rural family, women are generally the last to have their meals and hence are likely to receive a much smaller quantity of food during shortages. Drought also results in poorer health conditions of women because of their somewhat subordinate position in the family. When men migrate during drought years, women become the de facto heads of the household, and this increases their workload, as they have to manage the farm in addition to conducting the usual household chores (Rogaly et al 2002, Srivastava and Sasikumar 2003, Deshingkar and Start 2003, Shah and Shah 2005). Prolonged malnutrition and increasing workload during drought adversely affect women's health, especially of pregnant and lactating mothers. Infants and young children also suffer adversely as a result.

## 7.3 Expenditure adjustments

Forced adjustment in expenditure is a logical consequence of income loss. Reduced expenditure on some nonessential items such as clothing and social functions will not have major welfare implications. However, farmers often reduce expenditure even on essential items like food and medical treatment. Such expenditure cuts are most likely to result in adverse short- and long-term consequences. More than 50% of the farmers also reported curtailing children's education (Table 4.32). This occurs for

[10]Such consumption items include wild flowers and fruits, wild root and tuber crops (*konda*), wild leaves and vegetables, Kendu fruits, boiled Mahua flower, minor millets, broken rice, and boiled maize.

**Table 4.33. Percentage point changes in frequency of households engaged in cash and kind borrowing during a drought year versus a normal year, eastern India.[a]**

| Borrowed items | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Cash | 8 | 0 | 21 |
| Rice | 7 | 6 | 12 |
| Nonrice food | 6 | 1 | 11 |
| Seed of rice | 20 | 0 | 21 |
| Seed of nonrice food crops | 16 | –1 | 3 |
| All of the above | 28 | 7 | 30 |

[a]Positive numbers indicate an increase in frequency during drought years.

three reasons. First, parents may be unable to meet the recurring cost of education, although such expenditure may be small in an absolute amount. Second, adolescent children may be pulled out of school to work as labor to augment family income. Third, children leave school to accompany their migrant parents. Such parents are unlikely to be able to re-enroll the children in the new location due to the seasonal nature of migration. A lack of familiarity with the new location and poor social integration of the seasonal migrant community with local residents may aggravate the problem. Whatever the reason, interruption and/or discontinuation of children's education is a disinvestment in human capital that will most definitely reduce their future earning potential. Thus, an important pathway for escape from poverty may be foreclosed as a result of drought.

## 7.4 Credit

Borrowing to smoothen seasonal fluctuations in agricultural income is a normal and regular activity in rural areas. Borrowing may be both in cash and in kind. During periods of distress such as drought, reliance on borrowing tends to increase. Survey data indicated that the number of farmers who borrow increased during drought years. Farmers borrowed mainly cash, rice for consumption, rice seeds, other food crops, and seeds of other crops. The reliance on borrowing as a drought management strategy, however, varied across states. In Orissa, for example, 21% more farmers practiced cash borrowing during drought years relative to normal years (Table 4.33). More farmers also borrowed rice seeds. The incidence of cash borrowing, however, did not increase in drought years in Jharkhand. In the tribal-dominated areas of Jharkhand, the incidence of credit use may be somewhat limited due to legal restrictions placed on the mortgage of land that is under tribal ownership.

The average amount of cash and kind borrowing per household is \$5–9 and \$1–2 in normal years, respectively. It increases to \$7–14 and \$2–9 in drought years, respectively. A majority of farmers borrowed to meet consumption needs. Local merchants and moneylenders are the main source of credit, as institutional lending for consumption purposes is not widely practiced in the study area.

**Table 4.34. Percentage point changes in frequency of households engaged in selling of productive assets during a drought year versus a normal year, eastern India.[a]**

| Type of asset sold | Chattisgarh | Jharkhand | Orissa |
|---|---|---|---|
| Animals[b] | 13 | 2 | 24 |
| Farm tools | 8 | 3 | 8 |
| Land and building | 7 | 0 | 1 |
| All of the above | 21 | 3 | 25 |

[a]Positive numbers indicate an increase in frequency during drought years.
[b]Animals refer to the large animals, namely, cows, buffalo, bullocks, and pigs.

Borrowing does not have adverse welfare consequences when credit markets are competitive. However, adverse economic and social consequences can arise in rural areas where credit markets are poorly developed. When credit markets are not competitive, lenders may be able to extract more payments from borrowers by raising the interest rate and/or by extracting additional payments in other ways. Borrowers reported that the interest rate for borrowing during drought years increases by five to nine percentage points. For Orissa, farmers reported an average interest rate of as much as 34% per annum during drought years. Such a high interest rate obviously could force poor farmers into a perpetual debt trap.

### 7.5 Asset depletion

Liquidation of assets is an important mechanism for preventing consumption losses during drought years. Households may liquidate assets such as gold, ornaments, and jewelry that basically represent savings kept for possible future use. Liquidation of those assets does not entail economic costs. However, during a time of distress, farmers often liquidate their productive assets such as agricultural tools, draft animals, and even land. The sale of these productive assets can have a negative impact on agricultural productivity in subsequent years.

The incidence of liquidation/mortgage of these productive assets during drought years was found to increase in all the study villages. Again, the incidence of such asset sales was higher in Orissa than in Jharkhand (Table 4.34). The tribal-dominated areas of Jharkhand have some prohibitions on the liquidation of land and other properties held by tribal communities. This may have contributed to the lower incidence of the mortgage and sale of land in Jharkhand.

### 7.6 Livestock nutrition and mortality

A shortage of crop residues and other forms of animal feed during drought years can result in poor animal health and increased mortality. As a result, the percentage of households that were unable to provide the usual quantities of paddy straw and green grass to their livestock increased during drought years. Similarly, fewer households were able to provide oil cakes that are normally used as feed supplements. Instead, open grazing on dry leaves, grasses, and other plant species of low nutritional value

**Table 4.35. Percentage point changes in frequency of households collecting various forest produce during a drought year versus a normal year, eastern India.[a]**

| Forest produce | Regularly | | | Occasionally | | |
|---|---|---|---|---|---|---|
| | CH | JH | OR | CH | JH | OR |
| Fodder | 21 | 9 | 13 | 3 | 8 | –3 |
| Fuel wood and timber | 16 | 6 | 19 | 15 | 10 | 5 |
| Medicinal plants | 15 | 11 | 16 | 2 | 10 | 0 |
| Wild foods (plants and animals) | 12 | 19 | 28 | 6 | 0 | 0 |
| Other nontimber forest produce[b] | – | 11 | 12 | – | –8 | –1 |
| Other forest produce | 14 | 2 | 12 | 6 | 0 | –6 |

[a]Positive numbers indicate an increase in frequency during drought years. [b]Information for other nontimber forest produce for Chattisgarh is combined with the other forest produce category.

became the norm during drought years. Farmers reported a loss in the weight of draft animals and their strength as a consequence of poor feeding. Farmers also reported increased incidence of illness and mortality of livestock.

## 7.7 Use of forest and forest products

Farmers normally earn some income by selling forest products such as timber, medicinal plants, and wild food. Forests are exploited more intensively during drought years to supplement income. In addition, forests are used more intensively to supplement the household food supply. The number of farmers relying on forest products to supplement their income and food increased substantially in Orissa (Table 4.35). The reliance on forests and forest products was much less in Jharkhand in comparison.

Farmers reported that the average number of days of visits to forests per year increased during drought years. Using the number of days of visits to forests as an indicator of the intensity of forest use, small and marginal farmers were found to intensify forest use more than medium and large farmers. A majority of households also reported that forests became more degraded during drought years. Excessive exploitation during drought years can indeed result in a long-term decline in the productive capacity of forests.

## 7.8 Seasonal migration

Seasonal migration is widely practiced even during normal years in all three states. It is an important source of income, especially for small and marginal farmers whose land base is too small. Both the number of migrating households and the number of working days of migrants in all states increased during drought years. The overall incidence of migration increased by 6 to 18 percentage points while the number of working days increased from 32 to 94 days relative to normal years. This forced migration, while helping households cope with drought, can result in long-term adverse consequences, socially and economically. Invariably, migrant labor is paid lower wages than local labor. Sometimes, migrant families that migrate to distant places do not return in time to resume their normal agricultural activities even when the drought is over. Also, migrant labor generally ends up in jobs that are physically more demanding and with long working hours. These laborers also suffer from poor living conditions, such as in ghettos, and lack social integration with local communities.

### 7.9 Relief support

Government-sponsored relief programs can serve as an important safety net. Although the government of India spends a substantial amount of resources on relief programs (Samra 2004a), these programs do not seem to have reached needy people adequately. In the selected states, the number of households that participated in a drought relief program was relatively low and ranged from 10% to 28%. Moreover, the employment received from the program was also too low, ranging from 2.7 days in Jharkhand to 6 days in Chattisgarh, with annual income from relief ranging from $2 to $5 per household. The amount of assistance thus received is simply too low to sustain livelihood during drought periods. Relief operations suffer from several difficulties, including poor targeting as discussed in Section 9.

## 8. Economic costs of drought

The total economic costs of drought and employment loss due to drought are discussed in this section. The total economic costs of drought are estimated using four components directly associated with drought: the value of production loss during drought years, the ex ante cost associated with the opportunity loss resulting from a lower average productivity and the use of conservative practices, the cost of drought relief provided by the government and other agencies,[11] and the cost of mitigation programs implemented to reduce production loss. The ex ante economic costs of drought are estimated based on primary data and the economic costs of drought for the remaining three components are estimated using secondary data. The economic cost of each component during a drought year is weighted by the respective probabilities to estimate the annual average cost. The second-round effects of drought on the economy and the value of long-term production losses arising from a depletion in farm and human capital during drought years are not included due to the unavailability of suitable multiplier coefficients to translate direct production effects into these second-round and long-term effects. The estimate derived here thus represents a lower-bound value. The different components associated with the total economic costs of drought are discussed as follows.

### 8.1 Value of production losses

The value of production losses for both rice and major nonrice crops is estimated using the drought dummy model. The average production losses during drought years using both approaches (i.e., rainfall-based and government-declared) are close (Table 4.14).

[11] Although this is a transfer payment and does not represent a true economic cost, opportunity costs may be incurred with the use of scarce capital for providing relief.

Only the production losses estimated based on the rainfall-based drought dummy are discussed here. The estimated average value of total crop (rice and nonrice) production losses during drought years for the three states combined approximates $856 million. This is an estimate of loss from drought when it affects all three states simultaneously. For each state, the loss estimate is weighted by the probability of drought to obtain the average annual loss in crop production over the 33-year period analyzed. The total value of production losses annually for the three states combined is estimated at $162 million (Table 4.15).

## 8.2 Ex ante cost

The cost of ex ante coping mechanisms is estimated here using an approximation of the full approach discussed in Chapter 3. Knowing that droughts are regular phenomena that cannot be predicted accurately, farmers would have evolved conservative practices that give them some safety even though such practices may result in income losses during normal years. The cost of these conservative practices is the income forgone in the pursuit of safety. In addition, the drought-prone fields may have an intrinsically low average productivity relative to irrigated fields with adequate water supply. The ex ante cost is the sum of these two components. This forgone income can be estimated by comparing the net income of rice from fields that are drought-prone with the net income from better-endowed fields in terms of moisture availability. A first approximation of this is produced by comparing the rice yields in these two types of fields during normal years. The difference in yield between irrigated and rainfed fields during normal years provides such an estimate. The estimate of this difference for the study location is in the range of 0.5–1.2 t $ha^{-1}$. The lower value of this range is applied to rainfed drought-prone areas that include upland, medium land, and shallow lowland. These areas account for approximately 50% of the total rice area in each state. The use of the lower-end estimate from this range also helps to account partially for the differences in input use between irrigated and drought-prone fields as no data on input use were collected for irrigated fields during the survey.

The value of this loss is then weighted by the probability of occurrence of normal years. The total annual opportunity cost of drought to farmers in these three states of India is approximately $250 million per year (Table 4.36). This is the sum of the two components of ex ante costs mentioned in the previous paragraph. The estimates of these two components could not be obtained separately due to data limitations. It is worth noting that the opportunity cost estimated in this fashion is greater than the value of annual average production loss. This may seem to be a somewhat surprising result but arises from the assumption made in the estimation process that the difference in rice yields between drought-prone and irrigated fields even during "normal" years is attributable to the long-term yield-depressing effects of drought. As mentioned in the previous paragraph, this long-term effect arises from the intrinsically lower productivity of drought-affected fields and the farmers' use of conservative practices.

**Table 4.36. Ex ante economic costs of drought, eastern India.[a]**

| Ex ante costs | Chattisgarh | Jharkhand | Orissa | Total |
|---|---|---|---|---|
| i) Drought-prone rainfed rice area (million ha)[b] | 1.88 | 0.73 | 2.26 | 4.87 |
| ii) Lower-bound rice yield difference between irrigated and rainfed fields in normal year (t ha$^{-1}$)[c] | 0.50 | 0.50 | 0.50 | 0.50 |
| iii) Forgone production during normal year (million t)[d] | 0.94 | 0.36 | 1.13 | 2.44 |
| iv) Value of production forgone (million US$)[e] | 117.50 | 45.00 | 141.25 | 305.00 |
| v) Probability of occurrence of normal year (*P*)[f] | 0.85 | 0.82 | 0.79 | – |
| vi) Average ex ante cost of drought (million US$)[g] | 99.88 | 36.90 | 111.59 | 248.37 |

[a]For the procedure used here to estimate the ex ante cost, please refer to the text. [b]Considering upland, medium land, and shallow lowland. [c]Obtained from the farm data. [d]Obtained as the product of (i) and (ii). [e]Obtained using the price of rice at US$125 per ton. [f]Estimated as (1 – probability of drought), from Table 4.15. [g]Obtained as product of (iv) and (v).

## 8.3 Cost of watershed programs

At an average cost of approximately $52,000 per watershed project (this cost estimate is derived from the cost and the number of watershed projects in Orissa as indicated in Section 10), the total cost of watershed development programs is estimated to be $6.3 million for Chattisgarh, $1.0 million for Jharkhand, and $8.3 million for Orissa. This adds up to a total of $15.6 million. Assuming that this amount was spent over the past 10 years, the average cost per year is $1.6 million (Table 4.37).

## 8.4 Cost of relief operations[12]

The cost of relief operations is estimated based on the amount of cash spent and food grain provided from the National Calamity Contingency Fund (NCCF) for Chattisgarh, Jharkhand, and Orissa during the drought year of 2002. The total cash assistance from NCCF was $29.2 million for Chattisgarh, none for Jharkhand, and $1.2 million for Orissa. The value of food grain for relief employment was $54.2 million for Chattisgarh, $4.6 million for Jharkhand, and $48.3 million for Orissa. Thus, the total value of assistance received during the drought year of 2002 was $83.4 million for Chattisgarh, $4.6 million for Jharkhand, and $49.5 million for Orissa. Given that this amount is spent during a drought year, the values are weighted with respective probabilities of drought to derive an annual cost of relief operations. Thus, the annual cost of relief operations is estimated at $12.6 million for Chattisgarh, $0.8 million for

[12]Please note that although relief operations are of the nature of transfer payments, opportunity costs may be incurred in using scarce capital for this purpose.

**Table 4.37. Average annual total economic costs of drought (million US$), eastern India.**

| Total costs of drought | Chattisgarh | Jharkhand | Orissa | Total |
|---|---|---|---|---|
| Value of production loss due to drought | 39 | 22 | 101 | 162 |
| Ex ante economic costs of production adjustment | 99.88 | 36.90 | 111.59 | 248.37 |
| Costs of watershed programs[a] | 0.63 | 0.10 | 0.83 | 1.56 |
| Costs of relief operations[b] | 12.64 | 0.83 | 10.50 | 23.97 |
| Total economic costs | 152.15 | 59.83 | 223.92 | 435.90 |

[a]At the average cost of approximately $52 thousand per watershed project (this cost estimate is derived from the cost and the number of watershed projects in Orissa), the total cost of watershed development programs is estimated to be $6.3 million for Chattisgarh, $1.0 million for Jharkhand, and $8.3 million for Orissa. This adds up to a total of $15.6 million. Assuming that this amount was spent over the past 10 years, the average cost per year is $1.6 million. [b]The cost of relief operations is estimated based on the amount of cash and food grain spent from the National Calamity Contingency Fund (NCCF) for Chattisgarh, Jharkhand, and Orissa during the drought year of 2002. The total cash assistance from NCCF was $29.2 million for Chattisgarh, none for Jharkhand, and $1.2 million for Orissa. The value of food grain for relief employment was $54.2 million for Chattisgarh, $4.6 million for Jharkhand, and $48.3 million for Orissa. Thus, the total value of assistance received during the drought year of 2002 was $83.4 million for Chattisgarh, $4.6 million for Jharkhand, and $49.5 for Orissa. Given that this amount is spent during a drought year, the values are weighted with respective probabilities of drought to derive an annual cost of relief operations. Thus, the annual cost of relief operations was estimated at $12.6 million for Chattisgarh, $0.8 million for Jharkhand, and $10.5 million for Orissa, with a total of $24.0 million for the three selected states.

Jharkhand, and $10.5 million for Orissa, with a total of $24.0 million for the three selected states (Table 4.37).

## 8.5 Employment effect of drought

The effect of drought on employment loss in rice and nonrice crops in three states in eastern India is estimated using secondary data. Assuming that the employment elasticity of rice output is 0.6 (Bhalla 1987), a 10% reduction in output will lead to a 6% reduction in employment.[13] The average rice output reduction of 94%, 59%, and 60% in Chattisgarh, Jharkhand, and Orissa, respectively, during a drought year will thus reduce employment in rice production by 56%, 35%, and 36%, respectively. Assuming that rice requires 120 person-days per ha, the employment in rice production in Chattisgarh, Jharkhand, and Orissa in normal years is approximately 450 million, 180 million, and 540 million person-days, respectively. The loss in employment in rice production will thus be about 260 million, 60 million, and 190 million person-days for three states, respectively. If the losses in employment in the production of pulses and oilseeds are also added, the total loss of employment in agricultural production for the three selected states may be on the order of 290 million, 70 million, and 260 million person-days, respectively, with a total of 620 million person-days combined for three states. The second-round effects of such a massive loss in employment and earning opportunities will certainly be quite large. If 75% of the farm households be-

[13]The employment loss estimated in this way is applicable only when farmers are unable to plant rice due to early-season drought. Estimates will be lower when drought occurs later in the season when employment in harvest and postharvest operations is affected. Thus, the estimate of employment loss derived here is an upper-bound value.

long to small and marginal categories and may be in need of drought relief, the public relief program will need to generate almost 460 million person-days of employment in drought years. At the wage rate of $1 per person-day, additional employment will cost $460 million for the three states combined.

It should be noted that the loss in employment will have financial consequences for the people affected. Nevertheless, as labor is a production input, this employment loss is already captured in the economic value of losses in production. Hence, it is not included in the total economic cost to avoid double counting.

### 8.6 Total economic costs of drought

The total economic costs of drought are imputed as the sum of the first four components discussed earlier in this section. The estimated average annual total economic costs of drought for the three states combined are approximately $440 million (Table 4.37). The major component of these total economic costs is the cost of ex ante adjustments, which takes the form of opportunity cost during normal years. This ex ante cost accounts for about 57% of the total economic costs. The costs of relief and of watershed-based mitigation programs are relatively small and account for less than 6% of the total economic costs. The balance of about 37% is accounted for by the value of production loss.

Overall, the total economic costs of drought, as estimated in this study for the three states of eastern India, are substantial and account for about 11% of the combined agricultural GDP of these states.[14] Relative to this loss, the total expenditure in agricultural research and education in eastern India is estimated to be only about $100 million per year (Pal and Byerlee 2003). The investment in agricultural research and education certainly seems low relative to the size of the potential benefit that can arise from more effective drought mitigation. It is also observed that while past studies have focused on the value of production losses during drought years as a measure of economic cost, drought results in a loss in income even during normal years. This ex ante cost is indeed quite large and is estimated to be more than the value of production losses. Thus, past studies seem to have underestimated the value of production losses substantially by considering production losses during drought years only.

## 9. Poverty impact of drought mitigation

It was shown earlier that drought results in an increase in the incidence and severity of poverty. A simple scenario analysis based on the assumed effects of improved technologies on rice area and yield is carried out to assess the likely impact of various interventions on poverty reduction. The scenarios include (a) 50% and 100% reduction in yield losses, (b) 50% and 100% reduction in area loss, and (c) reductions in area and yield losses in different combinations. The effects of a reduction in losses of rice production on income are estimated at the household level by assuming that

[14]During 2000, the combined agricultural GDP of the three states was about $4.2 billion.

**Table 4.38. Modeling the effect of a reduction in rice area and yield loss due to drought on incidence of poverty, eastern India.**

| | Chattisgarh | | Jharkhand | | Orissa | | All |
|---|---|---|---|---|---|---|---|
| Rice area and yield simulation[a] | Percentage point reduction in poverty (% points) | Number of people affected (million) | Percentage point reduction in poverty (% points) | Number of people affected (million) | Percentage point reduction in poverty (% points) | Number of people affected (million) | Total number of people affected (million) |
| I | 13 | 2.16 | 2 | 0.42 | 4 | 1.25 | 3.83 |
| II | 31 | 5.15 | 5 | 1.05 | 6 | 1.87 | 8.07 |
| III | 1 | 0.17 | 3 | 0.63 | 3 | 0.94 | 1.73 |
| IV | 1 | 0.17 | 6 | 1.26 | 8 | 2.50 | 3.92 |
| V | 16 | 2.66 | 5 | 1.05 | 6 | 1.87 | 5.58 |
| VI | 33 | 5.48 | 12 | 2.51 | 16 | 4.99 | 12.99 |

[a]Rice area and yield simulation are defined as follows:
I: Loss in rice yield during drought years is reduced by 50%.
II: Loss in rice yield during drought years is reduced by 100%.
III: Loss in rice area during drought years is reduced by 50%.
IV: Loss in rice area during drought years is reduced by 100%.
V: Loss in rice area and yield during drought years is reduced by 50%.
VI: Loss in rice area and yield during drought years is reduced by 100%.

all other sources of income during drought years remain unchanged. Farm survey data are used to estimate the poverty impact of drought mitigation and results are presented in Table 4.38.

Under the scenario of a 50% and 100% reduction in yield losses, the poverty impact measured as percentage point reductions in poverty is highest in Chattisgarh. This is to be expected as drought results in a massive loss in yield in that state. If yield losses during drought years could be completely avoided, a total of eight million people from these three states would be prevented from falling into poverty.[15] This effect is equivalent to about a one percentage point reduction in rural poverty at the national level. Under the assumption of a reduction in yield losses by 50%, this number is reduced to about a half, that is, four million additional people will not fall into poverty relative to the current situation. Thus, even under this assumption, the poverty impact of drought mitigation is substantial. In addition to this impact on the incidence of poverty, the depth of poverty is also reduced as a result of drought mitigation as indicated under the scenario of a zero yield loss (Fig. 4.15).

Although the highest poverty impact is generated if yield losses could be completely prevented, the total effect of prevention in area losses is also not small. A 100% reduction in area losses produces the same total poverty impact as a 50% reduction in yield losses. This effect of preventing area losses arises mainly from Jharkhand

[15]Note that this scenario accounts for yield loss only, not for area loss, which may occur even when yield loss is completely avoided. Area losses occur when farmers fail to plant the crop due to early-season drought.

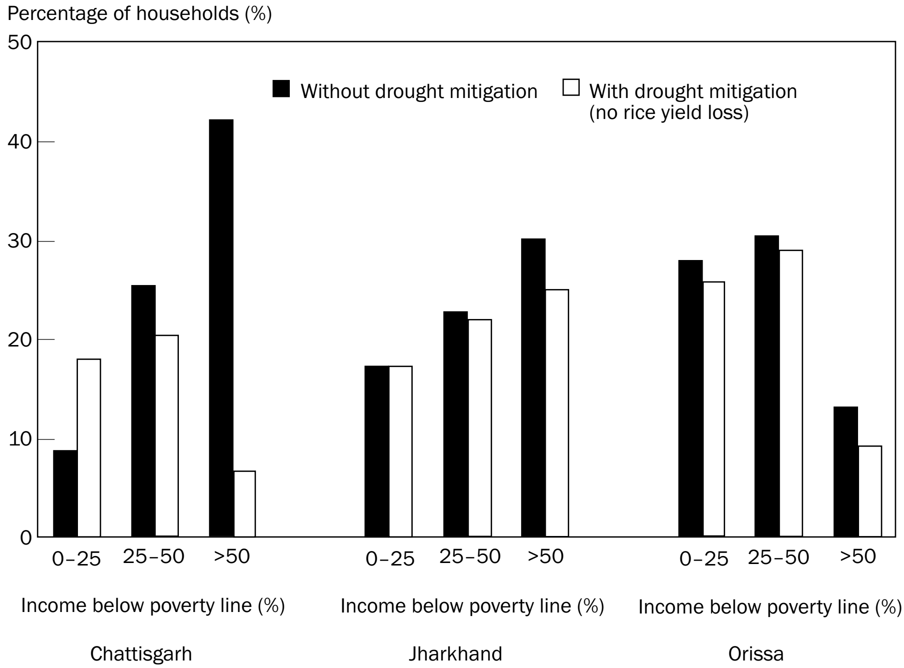



**Fig. 4.15. Frequency distribution of poverty depth in drought years with and without drought mitigation, eastern India.**

and Orissa, where droughts result in a much larger area effect than in Chattisgarh. Thus, while mitigation strategies that reduce yield losses are more important in Chattisgarh, the other two states would benefit substantially from the prevention of area losses also. This indicates that the poverty impact of different mitigation strategies varies across states.

## 10. Drought mitigation policies and institutional setup[16]

This section provides a critical overview of policies and institutional setup for drought management in India in general and in the selected three eastern Indian states (Orissa, Chattisgarh, and Jharkhand) in particular. The discussion is mainly based on secondary data and information available from different government and nongovernment sources.

[16]This section is an abridged extract of a consultancy report titled "Drought policy in the eastern Indian states of Chattisgarh, Jharkhand, and Orissa: an assessment." The report was commissioned as part of this research project and was prepared by Professor Indira Hirway, Director of the Center for Development Alternatives, Ahmedabad, India.

## 10.1 Drought policy in India

Policies for drought mitigation have a long history in India. Historically speaking, Muhammad Tughlakh was perhaps the first sultan to take systematic steps to alleviate the effects of drought (Loveday 1985). He distributed grains and provided loans and employment to people in Delhi for six months during the famine of AD 1343. During the British era, drought relief was provided under guidelines developed by Famine Commissions.

The first Famine Commission was set up to examine the causes and effects of drought in 1868 following droughts in Orissa in 1865-67. Another commission was set up in 1880, and both commissions recommended the use of relief and employment generation to prevent famines and death. The first Temporary Scarcity Manual was prepared by the British government of India in 1883. State governments subsequently prepared their own manuals using this central manual as the guide.

The current drought mitigation and relief policy of the central government of India has three major components: (1) drought/scarcity relief work; (2) drought-prone area development programs, that is, special programs designed to develop drought-prone and desert-prone areas; and (3) promotion of dry farming as part of the general agricultural policy.

Drought/scarcity relief is aimed at providing the required relief to drought-affected people. The approach is primarily based on principles accepted during the British period. Scarcity manuals of state governments today are based on those prepared during the British period. Though an attempt has been made to develop a new approach to "disaster management" under which all natural and manmade disasters are covered and "preparedness," "mitigation," and "prevention" are emphasized, no significant changes have been made in the basic strategy of providing relief to a drought-stricken population (Hirway 2001).

The basic approach consists of providing relief through the subsidized sale of food grains from buffer stock, income generation through public works, and the provision of seeds, fodder, and other agricultural inputs. The primary responsibility for providing relief is with the state governments. The state Relief Commissioner/Revenue Secretary is the nodal agency for relief efforts.

The drought-prone area development program is an area-based approach that aims at developing targeted areas that are suffering from frequent droughts. Various activities for the development of dry areas implemented up until the Fourth Plan period were redesigned and consolidated into Drought-Prone-Area Programs (DPAP). Similarly, efforts of desert development were channeled through the Desert Development Program (DDP), which started in 1974. In 1982, a review task force recommended the use of an integrated micro-watershed development approach, which involves the development of water resources through water harvesting, farm forestry, and the promotion of soil and water conservation practices. Various task forces and committees subsequently recommended the integration of different development activities, which are somewhat independent, into a comprehensive integrated watershed-based approach to development.

Over time, watershed development (WSD) programs have emerged as an important component of development in drought-prone areas. Recently, a new version of a WSD program, that is, Hariyali, was introduced by the government of India in 2003 (Ministry of Rural Development 2003). The main change is that the implementation of WSD programs will be made through Panchayati Raj bodies, which represent the basic political unit at the local level. Despite some positive achievements, the impact of these programs on drought-proofing has been limited (Rao 2000, Shah 2001b, Joy and Paranjape 2002, Kolavalli and Kerr 2002, Ghosh 2003).

To sum up, the three components of the drought policy have shown some convergence over time. Scarcity relief work is increasingly expected to include work that leads to drought-proofing. Watershed development programs are expected to develop drought-prone areas to achieve drought-proofing along with the promotion of agricultural growth. However, scarcity work is still carried out independently by the Revenue Department as a component of disaster management programs. The area development programs have not given enough focus on the critical needs for drought-proofing. In the final analysis, therefore, the major limitation of the drought policy today is the lack of integration between scarcity work and drought-proofing activities for promoting long-term agricultural growth.

## 10.2 Issues in drought policy in the eastern Indian states

The drought policy in all three states under study has essentially the three components mentioned above. These policies have, however, not achieved any substantial degree of drought-proofing, with the government having to overly rely on drought relief as the main mechanism to help the affected people. Several issues exist in relation to the current approach to drought mitigation. The major issues are discussed below.

*Absence of an integrated approach to fight droughts.* One major problem in all three states has been the lack of effective coordination among the three components of the drought policy. For example, the drought relief activities aim at providing immediate relief and protection against starvation and acute deprivation, but they lack a clear long-term focus for agricultural stabilization. The DPAP and WSD programs also lack a long-term focus on drought-proofing and on agricultural development. The agricultural development policies and programs are not adequately integrated with drought relief or watershed development projects. The net result is that all three components lack synergy in addressing the problem of drought adequately.

It needs to be noted, however, that the states have made some attempts in recent years to bring about some coordination between the three components. For example, drought relief work is now designed in consultation with the Departments of Agriculture, Rural Development, and Irrigation in all three states. In addition, efforts have been made to link watershed development with drought-proofing and poverty reduction, particularly in Orissa. However, these consultations and linkages are ad hoc, at best half-hearted, and not adequately supported by long-term policies.

*Design of drought/scarcity relief work.* Scarcity or drought relief work has an inherent disadvantage as it is based on the relief manual prepared during the British period. In spite of the modifications introduced over the years, the manual is still focused on “relief” and is implemented by a “law and order” department, that is, the Revenue Department. There are substantial lags in drought declarations and the mobilization of relief. In most cases, the coverage of the relief schemes is too small to have any substantial impact on the affected population.

The public relief work is also observed to be contributing much less to drought-proofing. Though all three states have made a decision to focus on public work that leads to drought-proofing, there is no clear long-term strategy or built-in plan for drought-proofing. Consequently, the selected work is not a part of a well-designed long-term strategy/plan. The shelf of projects at the district/block levels is usually a list of desirable projects and not the public work that is likely to lead to systematic drought-proofing. Also, the activities taken up are usually of short duration.. An important limitation of public work is that it is executed only during the scarcity period. There is not much chance that long-term work leading to drought-proofing will be undertaken under these programs.

*The Drought-Prone Area Program, watershed development, and drought-proofing.* There is no doubt that the performance of the DPAP has improved over the years, particularly after the introduction of the Watershed Development Program. Comprehensive evaluation studies of watershed development programs for Orissa, Jharkhand, and Chattisgarh are not available. Some limited studies, discussions with concerned persons, and the literature in this field do suggest that, on the whole, watershed development has helped in checking soil erosion, improving land cover, enhancing vegetation, and improving yields. However, several issues are important from the point of drought-proofing:

- WSD programs mostly focus on private (farm) lands, especially those of large farmers, and pay much less attention to small and marginal farmers as well as common lands. Thus, the projects usually neglect social and community aspects in terms of maintaining the security of food, water, fodder, fuel, etc., for the households.
- The sustainability of WSD is an important issue. It is observed that water harvested through watershed development is used up mostly by large farmers and the scarce water is not used efficiently. Such watersheds are not able to contribute to drought-proofing in the long run.
- WSD projects have a tendency to accentuate inequalities of assets and incomes in the region. This is because the benefits tend to accrue to farmers and not to the landless. Benefits from better soil and water management, better irrigation facilities, and increased agricultural production usually accrue to households with land, which enhances the income and asset base of those who have assets. Those without assets or the landless receive, at best, additional employment only.
- There has not been broad-based community participation in WSD projects. Strong community participation (of all groups) and institution-building are lacking in most WSD projects in these states.

Overall, drought management policies of the government of India and those in the states under study here have gone through a period of evolution from being relief-oriented only toward encouraging broad-based drought-proofing. However, the programs suffer from implementation difficulties that include design, targeting, and coordination aspects as well as a relatively small budget that limits the scope of coverage. As a result, the long-term mitigation of drought has not improved much. This has increased the need to provide more drought relief, which obviously cannot be provided adequately to everyone affected by drought. Farmers are often left to their own inadequate devices to cope with drought.

## 10.3 Institutional setup

The institutional and policy mechanisms for drought monitoring, early warning, forecasting, and impact analysis have been well defined and well established at both the central and state level. Drought management is a multidisciplinary function involving various ministries at different levels from center to state. Drought declaration is the responsibility of the state government, whereas the central government facilitates the process and provides support through physical and financial means in case of major droughts and through drought forecasting.

Drought monitoring is the responsibility of both the central and the state government, with frequent exchange of information. The Indian Meteorological Department (IMD), with the help of the interministerial Crop Weather Watch Group (CWWG), carries out drought forecasting at the national level. Using rainfall data from 2,800 rain gauge stations spread over 36 meteorological subdivisions in the country, the occurrence of meteorological drought is declared if the rainfall deficit is over 19% of the mean values (Samra 2004a). At the state level, the Department of Relief and Rehabilitation (DRR) or Department of Revenue (DR), with the help of the interdepartment CWWG, carries out drought monitoring and makes declarations.

The IMD forecasts of late arrival of monsoon and deficiency in rainfall from the mean values initiates the process of drought declaration. There are no universal criteria for declaring an agricultural drought. States follow certain directives for appraising agricultural losses and declaring drought in accordance with the Famine Code or Relief Manual. The system of estimating agricultural losses varies from state to state. Most states use an *Annawari* system (Samra 2004a), in which the normal and actual values of rainfall, crop area, and crop yield are analyzed by the *Annawari* committee[17] and this committee determines the occurrence of drought. The block is the basic unit of drought declaration.

There is an elaborate institutional setup from center to village for initiating drought relief (Fig. 4.16). The Ministry of Agriculture (MOA) is the nodal ministry for drought management at the central level. The central relief commissioner at the Department of Agriculture and Cooperatives (DAC) in the MOA at the central level, relief commissioner heading the DRR or the secretary heading the DR at the state level, deputy

[17]The committee consists of a chairperson (a circle inspector or deputy *mamlatdar* or extension officer or *gram sewak*) and members (*talati*, *sarpanch*, chairperson of cooperative society, and a farmers' representative).

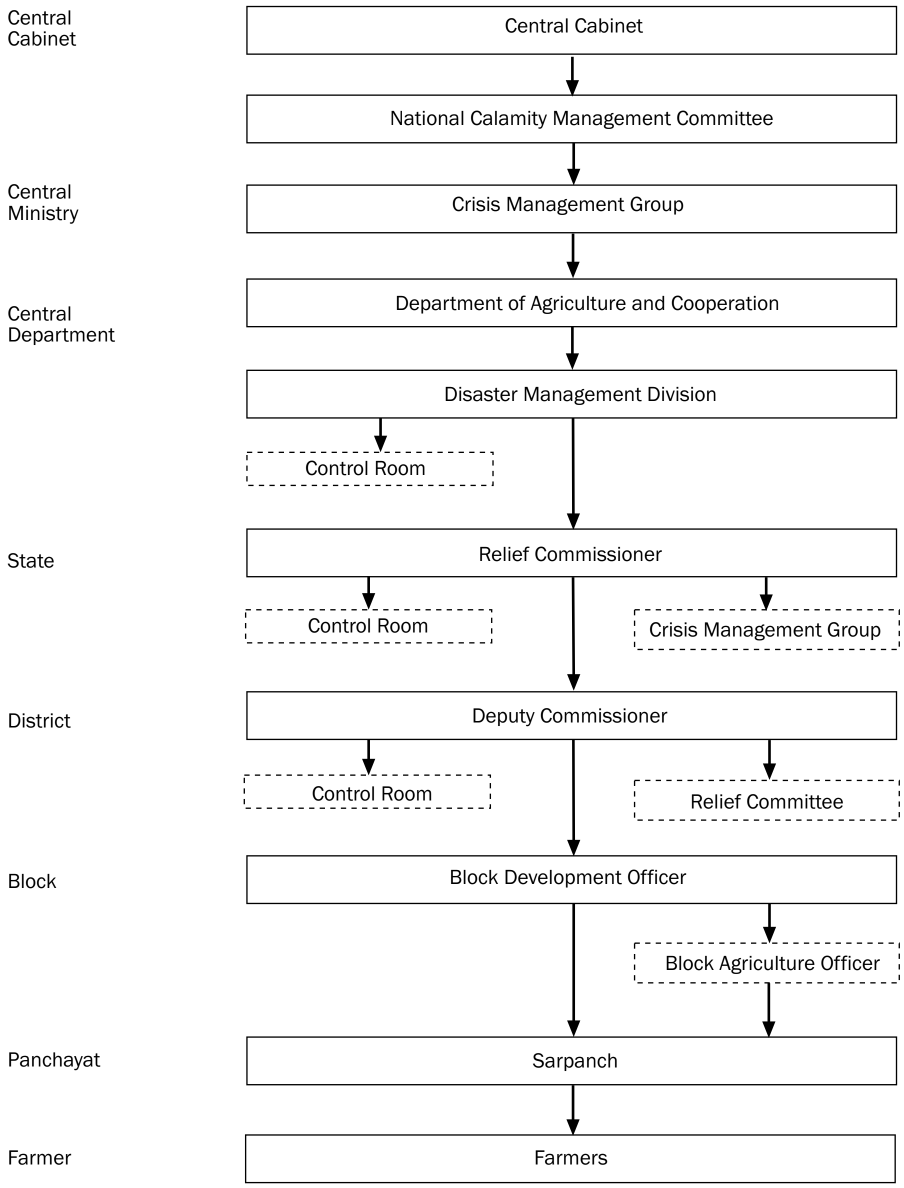



**Fig. 4.16. Flow chart of drought relief administration in India.**

commissioner/district collector at the district level, subdivisional officer/subcollector at the subdivisional level, block development officer (BDO) at the block level, and *sarpanch* at the *panchayat* level undertake drought management functions at their respective level. Information regarding the occurrence of drought and estimates of losses move up the system through this channel.

The central government established the Calamity Relief Fund (CRF) in 1995 to provide financial assistance to calamity-affected states. With the establishment of the CRF, the share of central and state government in total relief expenditure is 75% and 25%, respectively. The system of providing drought relief to farmers is well institutionalized from the center to the village level. The sanctioning of central government assistance to affected states involves three steps (Rathore 2004). First is the declaration of drought by the state. Second is the preparation of a Memorandum of Scarcity. Third is the constitution of a committee by the central government to verify the scarcity report submitted by the state. The first and second steps are undertaken by the affected state, while the third step is undertaken by the central government. On behalf of the central government, the DAC responds to the request of the state government. One of the additional secretaries at the department is permanently designated as the "relief commissioner" heading the Disaster Management Division to coordinate and monitor the drought situation for the entire country.

Once a drought has been notified by the state, it is mandatory for the center to designate a team of experts to verify the losses, as required by the state government. Upon receipt of a request for help from the state government, the Crisis Management Group (CMG) assesses the ground situation and formulates recommendations for assistance. Above the CMG is the National Calamity Management Committee (NCMC), which manages all calamities, including drought. It is headed by the cabinet secretary, with secretaries of the ministries and heads of agencies concerned with calamity-afflicted areas as members. Normally, any major calamity-related issues require a decision of the cabinet. However, during a major drought, ad hoc task forces are created to trigger a quick-response mechanism.

Overall, the administrative setup for drought monitoring and provision of relief have been established for a long time. However, there are substantial lags in the system, the amount of relief is limited, and those most in need often are not covered adequately. The process is somewhat top-down and participation of the local community is limited (Sainath 1996).

## 11. Conclusions and recommendations

The analysis of both the farm-level and district-level data presented in the study establishes clearly that drought is a recurring event in the humid and subhumid rice-growing areas of eastern India. Despite a high annual rainfall, a poor temporal distribution of rain results in periods of severe moisture deficiencies that adversely affect crop production. As the predominant form of agriculture in all three states considered in this report (Chattisgarh, Jharkhand, and Orissa) is rainfed, fluctuations in rainfall directly affect agricultural production.

The economic costs of drought to rainfed rice farmers and to the nation as a whole are on the order of several hundred million dollars per year. Farmers use various coping mechanisms to deal with the consequences of drought. These coping mechanisms are, however, inadequate to prevent a reduction in income and consumption, especially of the poor and vulnerable groups. Drought in these three states alone can push an additional 13 million people below the poverty line. In addition, people who are poor even during normal years get pushed deeper into poverty during drought years. Despite the considerable expenditures made to provide relief to drought-affected areas, to improve soil moisture availability through watershed programs, and to generally reduce vulnerability to drought through agricultural development programs, the overall economic and social costs of drought continue to remain high.

Obviously, this state of affairs suggests the need to develop more effective drought management strategies. Opportunities for technology development and policy reform for reducing the cost of drought and complementing farmers' coping mechanisms need to be considered. Technology improvements include the development of varieties that reduce losses to drought through various mechanisms such as drought escape, drought avoidance, and drought tolerance. Given that the growing season is short and drought during the reproductive stage is more important, improved rice varieties that are able to better tolerate such droughts are likely to be more effective in reducing production losses. However, improved varieties with such traits are generally unavailable in India. Research to develop such varieties needs to be adequately supported. However, the total expenditure in agricultural research (not just on drought research) in India has been very small relative to the economic costs of drought. For example, the total expenditure on agricultural research and education in eastern India is only about $100 million per year (Pal and Byerlee 2003) vis-à-vis the total economic costs of drought of approximately $440 million per year. The total expenditure on agricultural research in India during the 1990s was only 0.31% of the value of agricultural GDP, far below the developing country average of 0.62% (Pal and Byerlee 2003).

Rainfed environments are highly heterogeneous, with moisture availability varying even across fields. The level of research investment needed to characterize the nature of drought adequately, to develop a better understanding of genotype-environment interactions in drought-prone areas, and to understand the physiological basis for drought tolerance is certainly higher than what has been allocated in the past.

Despite the difficulties posed by the highly heterogeneous and variable nature of rainfed environments that have slowed progress in the past, opportunities for scientific progress in the future appear promising. One of the avenues is likely to be the use of biotechnology tools, gene mapping, and marker-aided selection (Bennett 1995). These modern tools that are now being increasingly used to complement conventional breeding have opened up a new frontier for developing improved germplasm efficiently. Similarly, new and improved scientific methods are being used to characterize drought and develop better strategies for plant breeding for drought-prone environments (Fukai et al 1997, Bellon and Reeves 2002, Fischer and Fukai 2003). Opportunities for improving moisture availability to crops through agronomic manipulation are similarly being evaluated (Fukai et al 1997).

In addition to improving productivity in drought-prone rainfed areas, improved rice technologies that perform well during drought are also likely to have spillover effects for irrigated areas. Projections on global water availability indicate that the future water supply to the agricultural sector is likely to diminish dramatically as the demand for water from industrial and urban sectors increases (Rosegrant et al 2002. Tuong and Bouman 2002, Bouman 2003). Rice varieties that tolerate drought will help maintain the productivity of irrigated rice in the face of a declining water supply. Given the critical importance of effective management of drought for enhancing food security and the availability of innovative tools, including molecular technology, it seems appropriate to reexamine the level of funding currently being allocated to drought research vis-à-vis other constraints such as pests.

Improvement in rice production technology is but one of the components of an overall strategy for effective drought mitigation. Augmentation of moisture availability to crops through water conservation, water harvesting, and watershed development is an important component of this. Conventional sources of irrigation such as those based on large dams and shallow groundwater are unlikely to be available to a majority of the farmers in drought-prone areas of eastern India. Hence, better management of local rainfall through water harvesting and moisture conservation measures can go a long way toward drought mitigation. Despite the implementation of watershed development programs in drought-prone areas, the lack of a comprehensive long-term strategy and poor implementation have constrained the effectiveness of these measures in drought mitigation (Rao 2000, Hirway 2001).

Drought management policies of the government of India and those in the states studied here have gone through a period of evolution from being purely relief-oriented toward achieving broad-based drought-proofing. However, these programs have suffered from difficulties such as poor design, poor targeting, and poor coordination among implementing agencies as well as a relatively small budget that limits the scope of coverage (Sainath 1996). Although watershed programs have important roles to play in soil and water conservation, they need to be better integrated with overall agricultural development policies. Similarly, the more effective use of rainfall through schemes such as water harvesting can have an important role in drought mitigation. The public investment in agricultural infrastructure to encourage a more effective use of rainwater and crop and income diversification for longer-term risk management has simply been inadequate.

Although technological interventions can be critical in some cases, these are not the only option for improving the management of drought. As discussed earlier, a whole gamut of policy interventions can improve farmers' capacity to manage drought through more effective income- and consumption-smoothing mechanisms. Improvements in rural infrastructure and marketing that allow farmers to diversify their income sources can play an important role in reducing overall income risk. Investments in rural education can similarly help diversify income. In addition, such investments contribute directly to income growth that will further increase farmers' capacity to cope with various forms of agricultural risks. Widening and deepening the rural financial markets will also be a critical factor for reducing fluctuations in both income and consumption over time. Although the conventional forms of crop insurance are unlikely to be successful due to problems such as moral hazard and adverse selection (Hazell et al 1986), innovative approaches such as rainfall insurance and international reinsurance of agricultural risks can provide promising opportunities (Walker and Ryan 1990, Gautam et al 1994). Improvements in drought forecasting and efficient provision of such information to farmers can similarly help improve their decisions regarding crop choice and input use (Abedullah and Pandey 1998). These institutional and policy interventions can be designed to complement technologies for a maximum impact. Although some progress has been made during the past decade, much remains to be done.

## References


Abedullah, Pandey S. 1998. Risk and the value of rainfall forecast for rainfed rice in the Philippines. Philipp. J. Crop Sci. 23(3):159-165.

Alwang J, Siegel PB, Jorgensen L. 2001. Vulnerability: a view from different disciplines. Social Protection (SP) Discussion Paper 0115. Human Development Network. Washington, D.C. (USA): The World Bank.

Bellon MR, Reeves J, editors. 2002. Quantitative analysis of data from participatory methods in plant breeding. Mexico, DF (Mexico): International Maize and Wheat Improvement Center (CIMMYT). 143 p.

Bennett J. 1995. Biotechnology and the future of rice production. GeoJournal 35(3):335-337.

Bhalla S. 1987. Trends in employment in Indian agriculture, land, and asset distribution. Indian J. Agric. Econ. 42(4):537-560.

Blaikie P, Cannon T, Davis I, Wishner B. 1994. At risk: natural hazards, people's vulnerability, and disasters. London (UK): Routledge Publishers.

Bouman BAM. 2003. Examining the water-shortage problem in rice systems: water-saving irrigation technologies. In: Mew TW, Brar DS, Peng S, Dawe D, Hardy B, editors. Rice science: innovations and impact for livelihood. Proceedings of the International Rice Research Conference, Beijing, 16-19 Sept. 2002. Beijing (China): International Rice Research Institute, Chinese Academy of Engineering, and Chinese Academy of Agricultural Sciences. p 519-535.

Brooks N, Adger WN, Kelly PM. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environ. Change 15:151-163.

Christiaensen LJ, Subbarao K. 2005. Towards an understanding of households' vulnerability in rural Kenya. J. African Econ. 14(2005):520-558.

DAC (Department of Agriculture and Cooperatives). 2004. Annual report 2003-04. Ministry of Agriculture, Government of India. New Delhi (India): Directorate of Economics and Statistics, Department of Agriculture and Cooperatives. 124 p.

Deshingkar P, Start D. 2003. Seasonal migration for livelihoods in India: coping, accumulation, and exclusion. Overseas Development Institute (ODI) Discussion Paper 220. London (UK): ODI.

Directorate of Agriculture and Food Production. 2004. Agricultural statistics of Orissa at a glance. 5th edition 2004. Bhubaneshwar (Orissa): Directorate of Agriculture and Food Production, Government of Orissa.

Downing TE, Bakker K. 2000. Drought discourse and vulnerability. In: Wilhite DA, editor. Drought: a global assessment, natural hazards, and disaster series. London (UK): Routledge Publishers. p 213-230.

Fischer KS, Fukai S. 2003. How rice responds to drought. In: Fischer KS, Lafitte R, Fukai S, Atlin G, Hardy B, editors. Breeding rice for drought-prone environments. Los Baños (Philippines): International Rice Research Institute. p 32-36.

Foster J, Greer J, Thorbecke E. 1984. A class of decomposable poverty measures. Econometrica 52(3):571-576.

Fukai S, Cooper M, Salisbury J. 1997. Breeding strategies for rainfed lowland rice in drought-prone environments. Proceedings of an international workshop held at Ubon Ratchathani, Thailand, 5-8 November 1996. Canberra (Australia): Australian Center for International Agricultural Research (ACIAR).

Gautam G, Hazell P, Alderman H. 1994. Rural demand for drought insurance. Policy Research Working Paper 1383. Agriculture and Natural Resources Department and Policy Research Department. Washington, D.C. (USA): The World Bank.

Ghosh S. 2003. Experience of NABARD in participatory area development projects. Ahmedabad (India): National Bank for Agriculture and Rural Development (NABARD).

Hazell P, Pomerada C, Valdes A. 1986. Crop insurance for agricultural development. Baltimore, Md. (USA): Johns Hopkins University Press.

Hirway I. 2001. Vicious circle of droughts and scarcity works: why not break it? Indian J. Agric. Econ. 56(4):708-721.

Hossain M, Sen B, Rahman HZ. 2000. Growth and distribution of rural income in Bangladesh. Econ. Political Weekly 35(52 & 53):4630-4637.

INDIAAGRISTAT. 2005. Database on Indian agriculture. New Delhi (India): Datanet India Pvt. Ltd. Online at www.indiaagristat.com.

Joy KJ, Paranjape S. 2002. Watershed development review: issues and prospects. Bangalore (India): The Center for Interdisciplinary Studies in Environment and Development (CISED).

Kamanou G, Morduch J. 2002. Measuring vulnerability to poverty. Discussion Paper 2002/58. World Institute for Development Economics Research (WIDER), United Nations University (UNU). Helsinki (Finland): The UNU/WIDER.

Katiyar VS. 1993. Human dimensions and drought management in India. Jaipur (India): Pointer Publisher.

Kolavalli S, Kerr J. 2002. Mainstreaming participatory watershed development. Econ. Political Weekly, 19 January 2002.

Loveday A. 1985. History and economics of Indian famines. New Delhi (India): Usha Publisher.

Ministry of Rural Development. 2003. Guidelines for Hariyali. Government of India. New Delhi (India): Ministry of Rural Development. 18 p.

Morduch J. 1994. Poverty and vulnerability. Am. Econ. Rev. 84(2):221-225.

Nagarajan R. 2003. Drought: assessment, monitoring, management, and resources conservation. New Delhi (India): Capital Publishing Company. 312 p.

NCAP-IRRI eastern India rice database. 2002. Time-series area, production, and yield of rice and monthly rainfall database. Los Baños (Philippines): International Rice Research Institute.

NIRD (National Institute of Rural Development). 2000. India's rural development report: regional disparities in development and poverty. Ministry of Rural Development and Poverty Alleviation, Hyderabad, India.

PACS (Poorest Areas Civil Society). 2004. Drought in India: challenges and initiatives. New Delhi (India): PACS programs. Online at www.empowerpoor.org.

Pal S, Byerlee D. 2003. The funding and organization of agricultural research in India: evolution and emerging policy issues. National Center for Agricultural Economics and Policy Research (NCAP) Policy Paper 16. New Delhi (India): Indian Council for Agricultural Research (ICAR). 53 p.

Pandey S, Barah BC, Velasco L. 2004. Patterns of rice productivity growth in eastern India: implications for research and policy. Draft paper. Los Baños (Philippines): International Rice Research Institute.

Pandey S, Behura DD, Villano R, Naik D. 2000. Economic costs of drought and farmers' coping mechanisms: a study of rainfed rice systems in eastern India. IRRI Discussion Paper Series 39. Los Baños (Philippines): International Rice Research Institute. 35 p.

Planning Commission. 2002a. National human development report 2001. Yojana Bhawan, New Delhi (India): Planning Commission, Government of India, March 2002. 297 p. Online at http://planningcommission.nic.in.

Planning Commission. 2002b. The 10th five-year plan (2002-2007). Yojana Bhawan. New Delhi (India): Planning Commission, Government of India.

Rao CHH. 2000. Watershed development in India: recent experiences and emerging issues. Econ. Political Weekly, 4 November 2004.

Rathore JS. 2004. Drought and household coping strategies: a case of Rajasthan. Indian J. Agric. Econ. 59(4):689-708.

Rogaly B, Daniel C, Rafique A, Rana K, Sengupta A, Biswas J. 2002. Seasonal migration and welfare/illfare in eastern India: a social analysis. J. Dev. Studies 38(5):89-114.

Rosegrant MW, Cai X, Cline SA. 2002. World water and food to 2025: dealing with scarcity. Washington, D.C. (USA): International Food Policy Research Institute. 322 p.

Sainath P. 1996. Everybody loves a good drought story from India's poorest districts. New Delhi (India): Penguin Books India.

Samra JS. 2004a. Review and analysis of drought monitoring, declaration, and impact management in India. International Water Management Institute (IWMI) Working Paper Number 84-Drought Series Paper Number 2. Colombo (Sri Lanka): IWMI.

Samra JS. 2004b. Drought management in India. A newspaper article. The Jan Samachar: multilingual news and feature agency devoted to rural development, 19 August 2004. New Delhi (India). Online at www.jansamachar.net. Accessed on 10 March 2005.

Shah A. 2001b. Who benefits from participatory watershed development? International Institute for Environment and Development (IIED) Gatekeeper Series 97. London (UK): IIED. Online at www.iied.org.

Shah DC, Shah A. 2005. Migration in remote tribal areas: evidence form southwestern Madhya Pradesh. Indian J. Agric. Econ. 60(2):184-204.

SHAZAM. 2004. Shazam User's reference manual version 10. Vancouver (Canada): Northwest Econometricts.

Singh BB, Chaturvedi GS, Singh VN, Singh AK, Singh HP, Verma OP, Singh A, Prasad S, Kumar R. 2003. Collection, evaluation, and improvement of rice germplasm breeding population for drought tolerance at NDUAT center. In: Shashidhar HE, Hittalmani S, Joshi D, editors. Abstracts. Proceedings of the Third Workshop on Drought Tolerance in Rice (*Oryza sativa* L.), 22-25 July 2003. Bangalore (India): University of Agricultural Sciences and New York (USA): The Rockefeller Foundation.

Singh K, Ballabh V. 2002. Managing droughts: an overview of India's experience. A paper presented in the workshop on economic costs of drought and farmers' coping mechanisms: a cross-country comparative analysis, 7-8 Dec. 2004. Los Baños (Philippines): International Rice Research Institute.

Srivastava R, Sasikumar SK. 2003. An overview of migration in India, its impacts, and key issues: migrations, development, and pro-poor policy choices in Asia. London (UK): Department for International Development (DFID). Online at www.livelihoods.org/hot_topics/docs.

Tesliuc ED, Lindert K. 2004. Risk and vulnerability in Guatemala: a quantitative and qualitative assessment. Social Protection Unit Discussion Paper 0404. Human Development Network. Washington, D.C. (USA): The World Bank.

The Fertilizer Association of India. 2002. Fertilizer statistics 2001-02. New Delhi (India): The Fertilizer Association of India.

Tuong TP, Bouman BAM. 2002. Rice production in water-scarce environments. In: Kijne JW, Barker R, Molden D, editors. Water productivity in agriculture: limits and opportunities for improvement. The Comprehensive Assessment of Water Management in Agriculture Series, Volume 1. Wallingford (UK): CABI Publishing. p 13-42.

Umamaheswari L, Krishnamoorthy P, Nasurudeen P, Kolli RP. 2001. Patterns of droughts and survival strategies of farm households in a drought-prone district in Tamil Nadu. Indian J. Agric. Econ. 56(4):683-695.

UNDP (United Nations Development Programme). 2003. Concept Paper for national consultation workshop on Drought Risk Management and Mitigation. Jaipur (India): HCM RIPA, United Nations Development Program. Online at www.undp.org.in.

Verulkar SB. 2003. Breeding strategies for the development of drought tolerant rice cultivar at IGAU, Raipur. In: Shashidhar HE, Hittalmani S, Joshi D, editors. Abstracts from the proceedings of the third workshop on drought tolerance in rice (*Oryza sativa* L.), 22-25 July 2003. Bangalore (India): University of Agricultural Sciences and New York (USA): The Rockefeller Foundation.

Walker TS, Ryan JG. 1990. Village and household economies in India's semi-arid tropics. London (UK): Johns Hopkins University Press.

Widawsky DA, O'Toole JC. 1990. Prioritizing the rice biotechnology research agenda for Eastern India. New York, N.Y. (USA): The Rockefeller Foundation. 86 p.

WB (The World Bank). 2001. World development report 2000/2001: attacking poverty. Washington, D.C. (USA): The World Bank.

WB (The World Bank). 2005. Ethiopia risk and vulnerability assessment. Report no. 26275-ET. Human Development Group III, Africa region. Washington, D.C. (USA): The World Bank.

## Notes

*Authors' addresses:* H. Bhandari, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines, currently with Japan International Research Center for Agricultural Sciences, 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan; S. Pandey, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines, R. Sharan, Department of Economics, Ranchi University, Ranchi 834 008, Jharkhand, India; D. Naik, Orissa University of Agriculture and Technology, Bhubaneswar 751 003, Orissa, India; I. Hirway, Center for Development Alternatives, Ahmedabad, India; S.K. Taunk, Indira Gandhi Agricultural University, Raipur (M.P.) 492 012, India; and A.S.R.A.S. Sastri, Indira Gandhi Agricultural University, Raipur (M.P.) 492 012, India.

*Acknowledgments:* This research was supported by a grant from the Rockefeller Foundation. We are grateful to Dr. John O'Toole, former associate director of the Foundation, for encouragement and support. We acknowledge administrative support from Ranchi University, Jharkhand; Indira Gandhi Agricultural University, Chattisgarh; and Orissa University of Agriculture and Technology, Orissa. Finally, our thanks go to the farmers who agreed to be included in the survey and provided valuable information, and to the local authorities who helped implement the field work.

CHAPTER 5

# Economic costs of drought and rice farmers' drought-coping mechanisms in northeast Thailand

P. Prapertchob, H. Bhandari, and S. Pandey

## 1. Introduction

Drought is an important constraint to agricultural production in Thailand. In addition to rice, it also adversely affects many other agricultural and allied economic activities (KRC 2004). Major drought years in Thailand are summarized in Table 5.1. One of the most severe droughts occurred in 1998. In the 1998-99 crop year, drought wreaked havoc on the farm sector and caused an estimated $290 million loss in farm income (Bank of Thailand 2005). Similarly, a serious shortage of water in major dams during 2004 due to drought resulted in a scarcity of water for consumption and agricultural use. More than 8 million people across 92% of the provinces were affected (Reuters 2005). Based on Bank of Thailand (2005) estimates, the drought of 2004 affected over 2 million ha (9.6%) of agricultural area in Thailand. Production losses from major crops were estimated to be $320 million, which is equivalent to 2.2% of agricultural GDP (Table 5.2). The drought-induced negative supply shock resulted in a 16.4% rise in aggregate crop prices compared to the previous year. The impact of this drought also continued into 2005. The production of major crops decreased by 16.7% and agricultural GDP dropped by 8.2% in the first quarter of 2005 vis-à-vis the same period of the previous year. Thus, the economic consequences of drought have been severe and spread throughout the economy in Thailand.

The overall objective of the study is to estimate the economic costs of drought and investigate farmers' drought-coping strategies in northeast Thailand, where rice production occurs mainly under rainfed conditions. The specific objectives of the study are as follows:

1. To understand the nature and magnitude of drought risk in drought-prone rice-growing areas of northeast Thailand,
2. To estimate the economic costs of drought at the aggregate level,
3. To analyze the economic consequences of drought at the farm-household level and farmers' drought-coping mechanisms,
4. To analyze strategies used by rice farmers to cope with drought, and
5. To suggest alternative options for technology and policy interventions for the effective management of drought risk.

**Table 5.1. Occurrence of drought in Thailand, 1950-2004.**

| Source | Drought years | | |
|---|---|---|---|
| | 1951-60 | 1961-80 | 1981-2004 |
| Steyaert et al (1981) | 1952, 1953, 1954, 1955, 1958 | 1966, 1967, 1968, 1972, 1974, 1976, 1977, 1978, 1979 | |
| TDRI (1994) | | | 1993 |
| University of Southampton (2001) | | 1978 | 1986, 1987, 1993, 1999 |
| TFRC (1998, 1999, 2002) | | | 1992, 1993, 1997, 1998, 1999, 2002 |
| Suwanabatr and Mekhora (2002) | | 1972, 1977, 1979 | 1998 |
| Ministry of Interior (2005) | | | 2001 |
| KRC (2004) | | | 2004 |
| All sources[a] | 1952, 1953, 1954, 1955, 1958 | 1966, 1967, 1968, 1972, 1974, 1976, 1977, 1978, 1979 | 1986, 1987, 1992, 1993, 1997, 1998, 1999, 2001, 2002, 2004 |
| Relative drought frequency (%) | 50 | 45 | 42 |

[a]Drought years reported in at least one of the sources listed above.

**Table 5.2. Economic impact of drought in Thailand.**

| Major drought years | Number of provinces affected | | Cropped area affected[a] | Economic losses[b] | |
|---|---|---|---|---|---|
| | (no.) | (% of total provinces) | (million ha) | (million US$) | (% of agricultural GDP) |
| 1992[a,c] | 46 | 61 | 1.07 | 210 | 2.8 |
| 1997[c] | 64 | 84 | 0.14 | 150 | 1.4 |
| 1998[d] | 72 | 95 | 0.85 | 290 | 2.4 |
| 2004[d] | 70 | 92 | 2.02 | 320[e] | 2.2 |

Sources:
[a]Affected cropped area was taken from MOAC (2003). [b]Exchange rate of US$1 = baht 41.2. [c]TFRC (1999). [d]Bank of Thailand (2005). [e]The estimated value of losses is derived from the losses in production of four major crops (rainy-season paddy, sugarcane, cassava, and maize) only. Losses in other crops and losses in export income from agriculture are not included in this estimate.

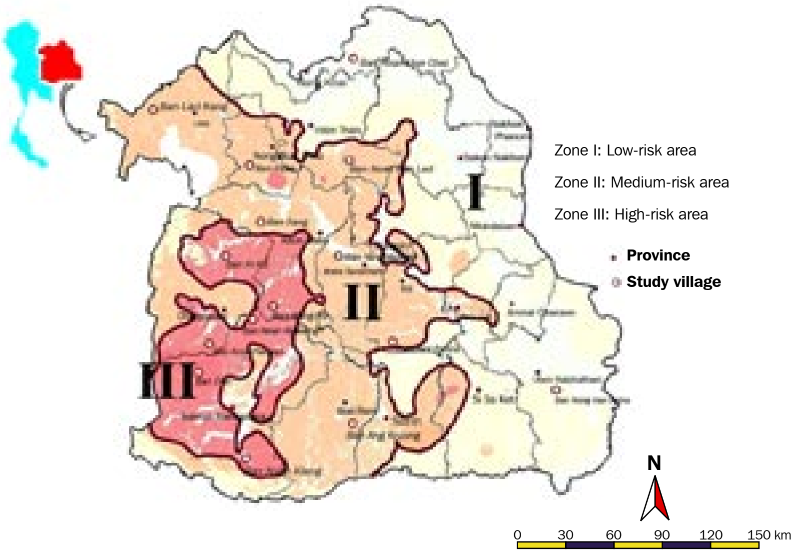



**Fig. 5.1. Map of northeast Thailand showing drought risk zones and study villages. Source: Mongkolsawat et al (2001).**

This chapter is organized into six sections. It begins with a general discussion of the drought problem in rainfed rice production systems of northeast Thailand. A short description of analytical methods used is provided in Section 2. The empirical findings of the study are described in subsequent sections. Section 3 includes the analysis of rainfall characteristics, estimates of the probability of drought, and estimates of production losses at the aggregate level. A discussion of household characteristics and production systems in a normal year, household-level impacts of drought, and farmers' drought-coping mechanisms is provided in Section 4. A critical overview of policies and institutional setup for drought management in northeast Thailand is included in Section 5. The final section concludes with a discussion of the overall implications for technology design and policy improvements for long-term drought mitigation in northeast Thailand.

## 2. Research design and data generation

This study focuses on northeast Thailand, which is classified into three zones based on the mean annual rainfall and magnitude of drought risk (Mongkolsawat et al 2001). The average rainfall is highest in Zone I and lowest in Zone III (Fig. 5.1). Zone I has six provinces and accounts for 38% of the total regional rice area. Zone II has the largest geographical area (eight provinces) and accounts for 49% of the total regional rice area. Zone III, however, has the smallest geographical area (two provinces) and

**Table 5.3. Triennium average area, yield, and production of rice, northeast Thailand, 2001-03.**

| Zone[a] | Area (000 ha) | Yield (t ha$^{-1}$) | Production (000 t) |
|---|---|---|---|
| Zone I | | | |
| Mean | 1,878 | 1.91 | 3,587 |
| Share in regional total (%) | 38 | | 37 |
| Zone II | | | |
| Mean | 2,456 | 2.02 | 4,950 |
| Share in regional total (%) | 49 | | 51 |
| Zone III | | | |
| Mean | 661 | 1.83 | 1,215 |
| Share in regional total (%) | 13 | | 12 |
| Northeast | | | |
| Mean | 4,995 | 1.95 | 9,752 |
| Thailand[b] | | | |
| Mean | 9,921 | 2.70 | 26,749 |

[a]Provinces included in each zone are as follows:
Zone I: Kalasin, Nakhon Phanom, Nong Khai, Sakon Nakhon, Sisaket, and Ubon Ratchathani.
Zone II: Buriram, Khon Kaen, Loei, Maha Sarakham, Roi Et, Surin, Udon Thani, and Yasothon.
Zone III: Chaiyaphum and Nakhon Ratchasima.
[b]The triennium average values for Thailand as a whole are estimated based on 2002-04 data.
Source: OAE (2004).

accounts for only 13% of the total regional rice area (Table 5.3). All provinces in northeast Thailand are included in this study.

Two types of analyses are conducted to meet the objectives of the study. The first involves an analysis of published temporal data on rainfall and crop production. Province-level temporal data on rice production and monthly rainfall covering 1970-2002 are used for characterizing drought and for estimating the impact of drought at the aggregate level. Analyses for zones and the northeast as a whole are done by aggregating the province-level data. Recorded rainfall data from different stations in each province are used to compute the mean monthly rainfall for each province, zone, and the northeast region as a whole. The average of rainfall recorded in all stations in a province is used to represent rainfall for the province.

Drought is defined in terms of deficiency of actual rainfall compared with the long-term average (LTA) rainfall. Following a similar approach used in other countries (Pandey et al 2000, Ding et al 2005), drought is considered to have occurred in a particular year if rainfall during the monsoon season (May-November) is less than 80% of the LTA. The major rice-growing season is divided into two periods—the early season (May-August) and the late season (September-November)—for assessing the incidence of drought during different periods and its impact on production. The frequency of drought during each period is estimated as the number of years in which rainfall is below 80% of the LTA for that particular period.

The basic analytical approach followed is described in Chapter 3. Two specifications are used to estimate the aggregate impact of drought on rice production. The first involves the estimation of a continuous relationship between production and rainfall using historical data. Production is expected to suffer when rainfall is too little or too much. This effect can be captured by specifying production (Q) as a quadratic function of rainfall:

$$Q = a + bT + cR + dR^2 + u \qquad (1)$$

where R is rainfall, T is a trend variable capturing the effect of technological changes, and $u$ refers to the random error term with the usual regression properties. In the specification above, the coefficients $c$ and $d$ measure the response to rainfall. It is anticipated that $c>0$ and $d<0$. This equation can be used to estimate the elasticity of production with respect to rainfall.

In the second specification for estimating production losses due to drought, a discrete drought dummy variable is specified in a linear trend equation. The model is specified as

$$Q = a + bT + cD + u \qquad (2)$$

As previously defined, T refers to the time trend that captures the effect of technological change and D is the drought dummy, which can be specified separately for different seasons. The drought dummy variable takes the value of 1 in drought years and zero otherwise. The coefficient $c$ measures the average effect of drought on production when all drought years are considered.

The production loss estimated above (i.e., based on rainfall or drought dummy) measures the average loss for drought years *only*. This needs to be weighted by the probability of drought to estimate the average loss *per year* over a run of years. The probabilities of drought estimated from the analysis of rainfall data are used for this purpose.

The second type of analysis involves the investigation of the household-level impact of drought and farmers' coping mechanisms. This analysis is conducted using data generated from farm household surveys. For this, households were selected from each of the three drought-risk zones using a stratified random sampling approach. Villages were selected to be representative of the drought-prone environment. A total of 300 farmers, comprising 20 randomly selected households each from 15 villages, were surveyed from the three zones. The details of sampling and the major characteristics of the production systems of the sampled areas are provided in Table 5.4. In addition to survey questionnaires, participatory rural appraisals, key informants surveys, focus group discussions, and case studies were conducted to collect qualitative information to complement the quantitative data. The survey was conducted in different periods during 2002. Representative normal and drought years identified by farmers for each village are presented in Table 5.5. The locations of the study villages are shown in Figure 5.1.

**Table 5.4. Sample selection scheme, northeast Thailand. Twenty households were surveyed in each area.**

| Zone | Province | District | Subdistrict | Village | Total households in the villages (no.) | Main characteristics of production systems |
|---|---|---|---|---|---|---|
| I | Ubon Ratchathani | Sawang Weerawong | Tha Khao | Nong Kaen Pattana | 58 | Low frequency of drought, low crop diversification, poor soils, poor farmers |
| | Nong Khai | Fao Rai | Nong Luang | Noan Meechai | 116 | Low frequency of drought, low crop diversification, poor soils, poor farmers |
| II | Loei | Phu Rue | Lad Kang | Lad Kang | 56 | Located in the hilly area, relatively good soil, some beans and other nonrice crops are planted |
| | Khon Kaen | Nong Rue | Noan Thong | Fang | 101 | Diversified farming, use of groundwater, planting several horticultural crops |
| | Nong Bua Lumphu | Sibun Rueng | Yang Lor | Pa Ka | 153 | Some weirs are nearby but most farmers did not get the benefit, receiving some government assistance but not enough |
| | Udon Thani | Kumpa Wapi | Chair Lae | Noan Hin Lad | 45 | Large sugarcane plantations, mixed farming of rice and sugarcane |
| | Mahasara-kham | Kosum Phisai | Lao | Yang Sinchai | 104 | Integrated farming was actively promoted, there was a rice seed production center, some farmers practiced organic farming |
| | Buriram | Krasang | Sung Nern | Ang Kruang | 66 | Located in dry area, traditional rice varieties widely preserved, glutinous-rice-eating village |
| | Roi Et | Kaset Visai | Dong Krang Yai | Noi Pattana | 76 | Located in the floodplain area of Tung Kula Ronghai, Hommali rice popularly planted |

*continued on next page*

**Table 5.4 continued.**

| Zone | Province | District | Subdistrict | Village | Total households in the villages (no.) | Main characteristics of production systems |
|---|---|---|---|---|---|---|
| III | Nakhon Ratchasima | Kang Sanamnang | Bung Palai | Noan Rawieng | 137 | Located in the sugarcane-planted area, moderate soil fertility, low rainfall |
| | Nakhon Ratchasima | Khonburi | Ban Mai | Noan Klang | 133 | Located in the ex-forest reserve area, there is an irrigation project nearby but villagers do not benefit, traditional rice varieties widely planted |
| | Nakhon Ratchasima | Dan Khuntot | Pan Chana | Don | 136 | Located in very dry area, farmers collect wild vegetables for sale, cattle raising popularly practiced |
| | Chaiyaphum | Kaset Somboon | Sa Poan Thong | Pi Puay | 171 | An irrigation project is nearby but villagers are not getting any benefit. It is located in the dry area. |
| | Chaiyaphum | Chaturat | Nong Bua Koak | Kroak Pak Warn | 71 | Farmers planted maize and chili with rice. It is located in a very dry area. |
| | Khon Kaen | Wangnoi | Kan Luang | Nong Ko | 148 | Farm ponds were popular among villagers, integrated farming is common, direct seeding is widely practiced |

**Table 5.5. Representative normal and drought years in study villages as identified by farmers, northeast Thailand.**

| Village name | Normal year | Drought year |
|---|---|---|
| Zone I | | |
| Nong Kaen Pattana | 2001 | 1996 |
| Noan Meechai | 2000 | 1999 |
| Zone II | | |
| Lad Kang | 1999 | 2001 |
| Fang | 2001 | 1998 |
| Pa Ka | 2001 | 1999 |
| Noan Hin Lad | 2001 | 2000 |
| Yang Sinchai | 1999 | 2001 |
| Ang Kruang | 1998 | 2000 |
| Noi Pattana | 2000 | 2001 |
| Zone III | | |
| Noan Rawieng | 2000 | 2001 |
| Noan Klang | 2000 | 1997 |
| Don | 2000 | 1998 |
| Pi Puay | 2001 | 1999 |
| Kroak Pak Warn | 2000 | 2001 |
| Nong Ko | 2001 | 2000 |

Source: Field survey. Information is collected during focus group discussions.

## 3. Aggregate-level analysis

This section describes the trends in rice production, characteristics of rainfall, and frequency of drought occurrence in northeast Thailand. In addition, rice production elasticity of rainfall as well as rice production losses due to drought at the aggregate level are estimated using the time-series data from 1970 to 2002. The results and discussion in this section are based on the aggregate- (province or zone) level analysis.

### 3.1 Trends in rice production in northeast Thailand

Thailand is one of the major rice-growing countries and the world's top rice exporter. The 2002-04 triennium average rice area[1] and production were 10 million ha and 27 million tons, respectively. Rice area, yield, and production have been increasing over time (Fig. 5.2). The growth rate in rice production was 2% per annum over the period 1970-2004, with yield growth accounting for 59% of this production growth rate.

Rainfed lowland, the most predominant rice ecology, occupies 66% of the total rice area, whereas irrigated, deepwater, and upland rice ecologies occupy 32%, 2%, and less than 1% of the total rice area of the country, respectively (Kupkanchanakul 2000). Only a single crop of wet-season rice is grown in rainfed areas. During the triennium 2000-02, wet-season rice accounted for 86% of the annual rice area and

[1]In this report, rice area refers to the harvested area of rice as reported in the agricultural statistics of Thailand.

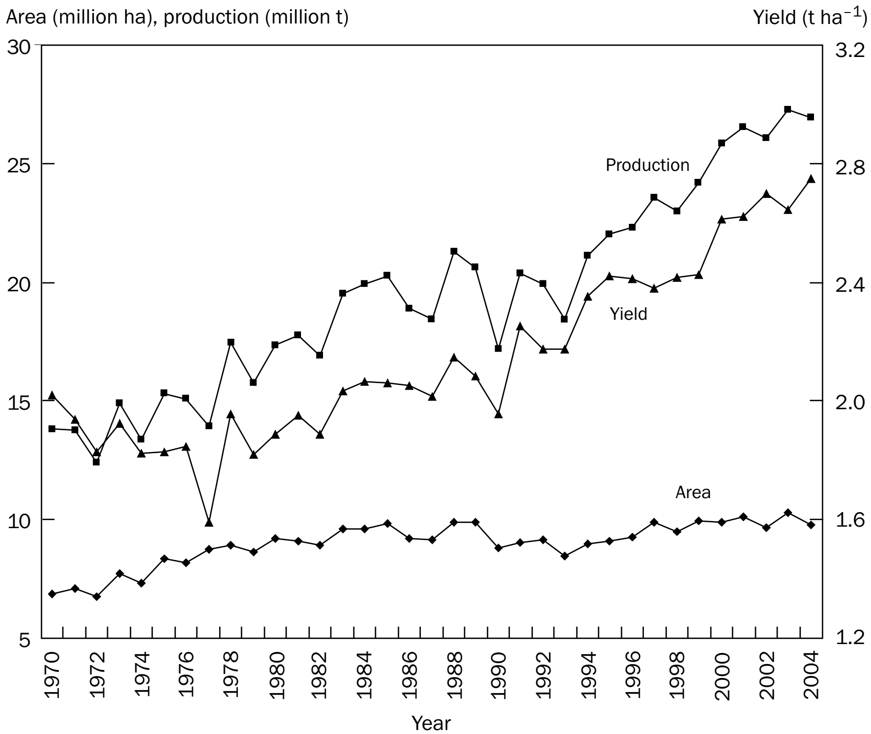



**Fig. 5.2. Trends in rice area, yield, and production, Thailand, 1970-2004.**

contributed 77% to total production. In irrigated areas, rice is grown during the dry season also. The Central Plains of Thailand are the main belt for irrigated rice, with the major dams in the northern part being the main source of irrigation. Rainfed rice is grown mainly in the northeast, which accounts for 50% of the total area and 37% of the total rice production in Thailand. The region is well known for producing premium-quality fine-grain nonglutinous rice, which is mostly exported.

Northeast Thailand accounts for one-third of the total population and land area of the kingdom. It is bounded by the Mekong River in the north and east, and by gentle hills in the south and west. It comprises small hills, gently undulating areas, and plains.[2] Agriculture provides employment to nearly 70% of the region's population.

The climate of the northeast is warm tropical and is characterized by three distinct seasons: a cool season from November to February, a hot season from March to April, and a rainy season from May to October. The region is subject to a southwest monsoon that normally starts in May and ends in October.

[2]Northeast Thailand includes the Korat Plateau.

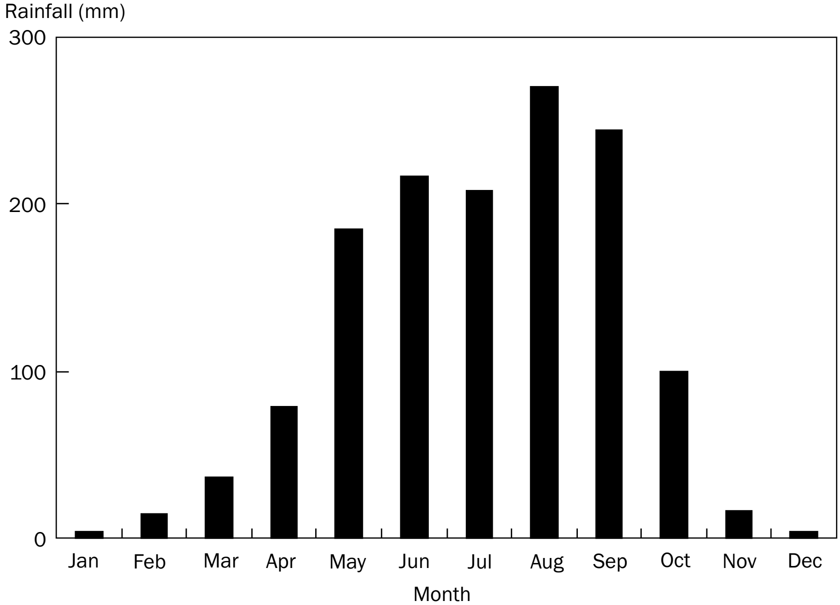



**Fig. 5.3. Long-term average monthly rainfall, northeast Thailand, 1970-2002.**

The irrigated area in the northeast accounts for 10% of the net cultivated area, while the corresponding value for the whole country is 25%. Thus, agriculture in the northeast is essentially rainfed. Rice is the main crop and it occupies about two-thirds of the cultivated land.

The rice area in the northeast increased from 3.5 million ha (1970) to 5.2 million ha (2003), with an annual growth rate of 1.1%. The regional rice yield of 1.5 t ha$^{-1}$ (1970) reached 1.9 t ha$^{-1}$ (2003), with an annual growth rate of 1.5%. As a result, regional rice production increased from 5.1 million tons (1970) to 10.0 million tons (2003).

## 3.2 Rainfall and drought characteristics

The average annual rainfall for the period 1970-2002 in northeast Thailand was 1,380 mm. The monsoon rains normally start in May and the amount of rainfall increases until June, reaches its peak in August, and starts declining afterward. The rainy season ends in November with the start of the dry and cold period (Fig. 5.3).

The mean monsoon rainfall of Zone I is substantially higher than that of Zones II and III (Table 5.6). In terms of mean rainfall, Zone I is thus less likely to suffer from drought relative to other zones. The CVs of monsoon rainfall for the three zones are similar and ranged between 11% and 12%. In terms of spatial distribution, the province-level annual rainfall ranges from 1,020 to 1,960 mm, with comparatively

**Table 5.6. Long-term average (mm) and coefficient of variation (%) of rainfall, northeast Thailand, 1970-2002.**

| Northeast region | Rainfall period[a] | | | |
|---|---|---|---|---|
| | Early | Late | Monsoon | Annual |
| | Long-term average rainfall (mm) | | | |
| Zone I | 1,120 | 350 | 1,470 | 1,610 |
| Zone II | 760 | 360 | 1,120 | 1,250 |
| Zone III | 520 | 370 | 900 | 1,040 |
| Northeast | 880 | 360 | 1,240 | 1,380 |
| | Coefficient of variation (%) | | | |
| Zone I | 15 | 24 | 12 | 12 |
| Zone II | 14 | 22 | 11 | 11 |
| Zone III | 19 | 23 | 13 | 12 |
| Northeast | 12 | 22 | 10 | 10 |

[a]Rainfall period is defined as follows: early: May-August, late: September-November, monsoon: May-November.

high values in Nakhon Phanom and Nong Khai and low values in Chaiyaphum and Nakhon Ratchasima (Fig. 5.4).

The distribution of annual rainfall is 64% in the early season (May-August), 26% in the late season (September-November), and 90% in the monsoon season (May-November). The overall CV of rainfall is 12% during the early season, 22% during the late season, and 10% during the monsoon season. Thus, rainfall is more variable during the late season, which is a critical period for rice yield formation. The CV of monsoon rainfall ranged from 12% to 22% across provinces. Substantial spatial variation exists in the total amount and distribution of rainfall in the northeast.

The frequency of drought estimated using the meteorological definition of drought is summarized in Table 5.7. Using this criterion, the important drought years in northeast Thailand are 1977, 1979, 1981, 1982, 1992, 1993, 1995, 1996, 1997, 2000, and 2004. The overall probability of drought is 9% during the early season and 20% during the late season. Thus, late-season drought is more frequent than early-season drought. At the zonal level, the probability of drought is 6–11% during the early season and 21–27% during the late season.

The probability of spatially covariate[3] drought is estimated using the province-level rainfall data. The estimated probability of covariate drought in northeast Thailand is 13% in the early season and 28% in the late season. At the zonal level, the probability of covariation was 13–22% during the early season and 23–45% during the late season. Late-season drought is thus more covariate than early-season drought. Overall, drought events in northeast Thailand are not highly covariate.

[3]Covariate drought years refer to those years in which drought occurred in over 50% of the provinces of the zone or region.

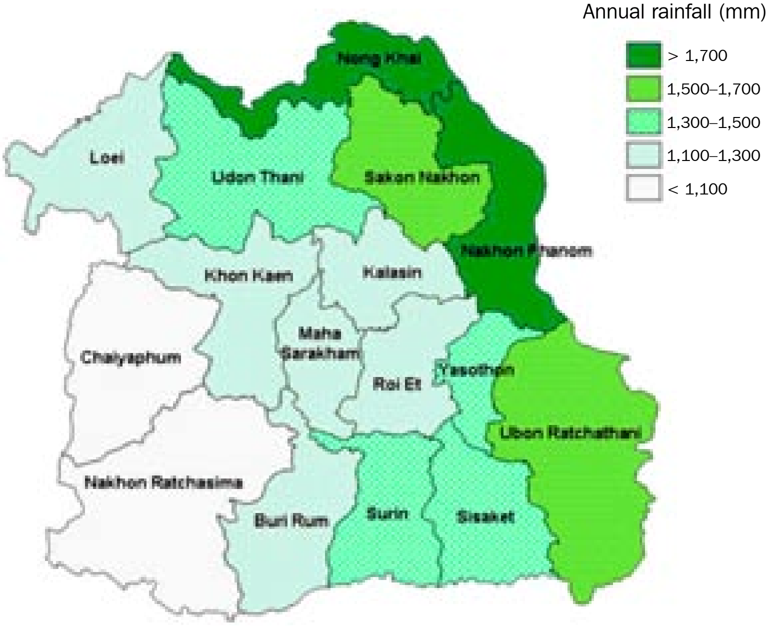



**Fig. 5.4. Long-term average annual rainfall, northeast Thailand, 1970-2002.**

## 3.3 Aggregate impact of drought

The observed temporal fluctuations in rice yield and area are the results of many stochastic factors, including drought. The size of the temporal fluctuations can therefore provide some indications of the likely overall magnitude of the effect of drought. Here, coefficients of variation (CV), estimated using linearly de-trended time-series data on rice area, yield, and production, are used for an initial analysis.

Overall, temporal variability in rice area, yield, and production as measured by the CV using 1970-2002 data for the whole country is 6%, 6%, and 7%, while it is 7%, 10%, and 10% for the northeast, respectively. Thus, rice production is relatively more unstable in the northeast than in the whole country.

The overall yield CV for the northeast as a whole is 10%, with the highest (14%) being in Zone III. The yield CV is 43% higher than the area CV, indicating high instability in yield compared with area. Across provinces, yield CV ranges from 8% to 19%, with relatively high values in Sisaket, Loei, and Chaiyaphum and relatively low values in Kalasin, Nong Khai, and Sakon Nakhon. Overall, rice production is most stable in Zone I and least stable in Zone III.

The yield fluctuations in rainfed lowland rice arise mainly due to low and erratic distribution of rainfall (Adulavidhaya 1979, Fukai and Cooper 1995). An analysis of time-series data between rainfall and yield can give some indication of the relationship

**Table 5.7. Frequency of drought in different seasons, northeast Thailand, 1970-2002.[a]**

| Northeast region | Rice-growing season | | |
|---|---|---|---|
| | Early | Late | Monsoon |
| Zone I | | | |
| Drought years | 1977, 1982, 1996, 1998 | 1973, 1974, 1979, 1992, 1993, 1995, 1997 | 1977 |
| Probability | 0.12 | 0.21 | 0.03 |
| Zone II | | | |
| Drought years | 1982, 1996 | 1979, 1981, 1986, 1992, 1993, 1997, 2000 | – |
| Probability | 0.06 | 0.21 | 0.00 |
| Zone III | | | |
| Drought years | 1972, 1974, 1981, 1987 | 1979, 1981, 1986, 1992, 1994, 1997, 1998, 2000 | 1981, 1997 |
| Probability | 0.12 | 0.24 | 0.06 |
| Northeast | | | |
| Drought years | 1977, 1982, 1996 | 1979, 1981, 1992, 1993, 1995, 1997, 2000 | – |
| Probability | 0.09 | 0.21 | 0.00 |

[a]Using the definition of drought, the probability of drought for the monsoon season (May-November) for the whole of northeast Thailand turned out to be virtually nil due to the averaging effect over such a large area and for the whole season, even though the crop may suffer from drought in some locations and during some growth periods.

between these two variables. The small correlation coefficient (r = 0.18) indicates a poor relationship between these two variables for northeast Thailand as a whole. This indicates that the impact of drought on rice yield and production in the region included in this study is unlikely to be substantial at the aggregate level.

To investigate the impact of drought further, elasticity of rice area, yield, and production is estimated using the methodology described in Section 2 (see Chapter 3 for details). Using the province-level rice production and monthly rainfall data from 1970-2002, the rainfall elasticity of rice planted area, yield, and production is estimated for each of the 16 provinces in the three zones, and the northeast region as a whole[4] (Table 5.8). The relevant statistically significant F-values ($P<0.1$) for area, yield, and production indicate that the models fit the data reasonably well. Very few elasticity coefficients, however, are found to be statistically significant.

The estimated area elasticities are statistically significant for Zones II and III but not for Zone I. The area elasticity of 0.48 in Zone III implies that a 10% deficit in

[4]In northeast Thailand, rice is normally planted during May to August and heading occurs during September to November. Hence, rainfall during May-August, September-November, and May-November is used to examine the effect of rainfall on rice area, yield, and production, respectively.

**Table 5.8. Rainfall elasticity estimates of rice area, yield, and production, northeast Thailand, 1970-2002.**[a]

| Province | Area | Yield | Production |
|---|---|---|---|
| Zone I | 0.06 | –0.05 | 0.01*** |
| Kalasin | 0.46*** | –0.02 | 0.44 |
| Nakhon Phanom | –0.08 | –0.05 | –0.13 |
| Nong Khai | 0.19 | 0.03 | 0.22 |
| Sakon Nakhon | 0.11 | –0.06 | 0.05 |
| Sisaket | 0.27 | 0.12 | 0.38 |
| Ubon Ratchathani | 0.18 * | –0.16* | 0.02 |
| Zone II | 0.32*** | 0.01 | 0.33*** |
| Buriram | 0.29 * | 0.00 | 0.28 |
| Khon Kaen | 0.69*** | 0.05 | 0.74*** |
| Loei | 0.12 | –0.17 | –0.05 |
| Maha Sarakham | 0.30 | 0.03 | 0.34*** |
| Roi Et | 0.08 | –0.08 | –0.01 |
| Surin | 0.66*** | –0.17* | 0.50*** |
| Udon Thani | 0.19 | 0.15* | 0.33** |
| Yasothon | 0.24** | –0.11 | 0.13 |
| Zone III | 0.48*** | –0.04 | 0.44** |
| Chaiyaphum | 0.71*** | –0.02 | 0.69*** |
| Nakhon Ratchasima | 0.38*** | –0.02 | 0.36 |
| Northeast | 0.17 | 0.00 | 0.16*** |

[a]Rainfall in May-August, September-November, and May-November is used to evaluate the effect of rainfall on rice area, yield, and production, respectively.
***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

rainfall from the average will reduce rice area by about 5% in this zone. Since drought here is defined as at least a 20% drop in rainfall, the corresponding reduction in rice area would be 10%. The comparatively high area response to drought in Zone III is probably due to the relatively low average rainfall and the poor-quality soils that have low water-holding capacity. Mongkolsawat et al (2001) also reported Zone III as the most drought-prone area in the northeast.

Contrary to the expectation, yield responses to drought are statistically significant only in three provinces. Moreover, the yield elasticity coefficients are negative in two provinces. The elasticity coefficients are not statistically significant in the rest of the provinces. Thus, the analysis shows weak correlations between deficiency in rainfall and rice yield.

The estimated production elasticities are statistically significant for all zones and the northeast as a whole. At the province level, production elasticities are found to be statistically significant only in five provinces that are located mainly in Zones II and III. There is a considerable variability in responses to a shortfall in rains across provinces. Area elasticities are statistically significant in more provinces than yield

**Table 5.9. Ordinary least square estimates of the effect of monsoon-season drought dummy on rice production, northeast Thailand, 1970-2002.[a]**

| Province | Coefficients of drought dummy | Adjusted R-square |
|---|---|---|
| Zone I | | |
| Kalasin | –41 | 0.52 |
| Nakhon Phanom | –22 | 0.87 |
| Nong Khai | –27 | 0.58 |
| Sakon Nakhon | –44* | 0.75 |
| Sisaket | –90 | 0.66 |
| Ubon Ratchathani | –205*** | 0.87 |
| Zone II | | |
| Buriram | a | 0.49 |
| Khon Kaen | –129*** | 0.47 |
| Loei | –26 | 0.60 |
| Maha Sarakham | –64 | 0.63 |
| Roi Et | 5 | 0.77 |
| Surin | a | 0.61 |
| Udon Thani | –107*** | 0.62 |
| Yasothon | 5 | 0.65 |
| Zone III | | |
| Chaiyaphum | –170*** | 0.34 |
| Nakhon Ratchasima | 109 | 0.62 |

[a]Dependent variable: production (000 t). Drought dummy is defined as years with monsoon-period (May-November) rainfall less than 20% of the long-term average. ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. “a” means there is no drought dummy coefficient due to the absence of a drought year for the province.

elasticities and the magnitudes are relatively higher, indicating that the effects of drought on production at the provincial level mainly arise through a reduction in rice area. Overall, the effect of rainfall variation in rice production is relatively weak, even though rice area planted and/or yield may be affected in some cases.

The effect of drought on rice production is also examined using the drought dummy variables (see Chapter 3 for details). The ordinary least square estimates of the effect of monsoon-season drought on rice production for each province are presented in Table 5.9. The coefficient of the drought dummy variable provides a measure of the average production losses during drought years. As expected, drought adversely affects rice production in all provinces except in three provinces where the estimated coefficients are positive but not statistically significant. The marginal coefficient of the drought dummy in Chaiyaphum implies that the average rice production loss in Chaiyaphum in drought years is 170,000 tons. The estimated average rice production loss during drought years ranges between 12% and 55% of the mean annual output in these provinces (Table 5.10). The coefficients associated with the drought dummy variable are statistically significant ($P$<0.1) in Sakon Nakhon and Ubon Ratchathani in Zone I, Khon Kaen and Udon Thani in Zone II, and Chaiyaphum in Zone III. Only

**Table 5.10. Estimation of rice production losses using monsoon-season drought dummy, northeast Thailand, 1970-2002.[a]**

| Province | Mean output (000 t) | Drought year production loss: Quantity (000 t) | Value (000 US$) | Percent (%) | Monsoon drought probability (*P*) | Annual production loss (%) |
|---|---|---|---|---|---|---|
| Zone I | | | | | | |
| Kalasin | 330 | 41 | 5,280 | 12 | 0.04 | 0.4 |
| Nakhon Phanom | 270 | 22 | 2,800 | 8 | 0.12 | 1.0 |
| Nong Khai | 240 | 27 | 3,540 | 11 | 0.12 | 1.4 |
| Sakon Nakhon | 350 | 44* | 5,660 | 12 | 0.09 | 1.1 |
| Sisaket | 480 | 90 | 11,740 | 19 | 0.04 | 0.7 |
| Ubon Ratchathani | 720 | 205*** | 26,710 | 29 | 0.06 | 1.7 |
| Zone II | | | | | | |
| Buriram | 610 | a | | | 0.00 | |
| Khon Kaen | 450 | 129*** | 16,780 | 29 | 0.15 | 4.3 |
| Loei | 130 | 26 | 3,450 | 20 | 0.09 | 1.9 |
| Maha Sarakham | 360 | 64 | 8,290 | 18 | 0.06 | 1.1 |
| Roi Et | 510 | b | | | 0.06 | |
| Surin | 570 | a | | | 0.00 | |
| Udon Thani | 630 | 107*** | 13,910 | 17 | 0.15 | 2.6 |
| Yasothon | 210 | b | | | 0.04 | |
| Zone III | | | | | | |
| Chaiyaphum | 310 | 170*** | 22,160 | 55 | 0.15 | 8.3 |
| Nakhon Ratchasima | 600 | b | | | 0.03 | |

[a]Dependent variable: production (000 t). Rice price of US$130 $t^{-1}$ is used to compute the value of production losses. The value of production losses was rounded off to the nearest tenths digit. Estimates of production losses are based on the monsoon drought dummy model. Drought dummy is defined as years with monsoon-period (May-November) rainfall less than 20% of the LTA. *** and * indicate statistical significance at the 1% and 10% levels of probability, respectively. Percentage refers to the proportion of sample mean production during 1970-2002. "a" means there is no drought dummy coefficient due to the absence of a drought year for the province. "b" means that the coefficient of drought dummy was positive and hence the value is not reported here.

statistically significant drought dummy coefficients are used to estimate the value of production losses due to drought.

The above estimate is the average value of losses for drought years *only*. As drought does not occur every year, this estimate needs to be multiplied by the probability of drought to arrive at the average annual loss. For this, province-level losses that are statistically significant are multiplied by the respective probabilities of drought and the expected loss for the northeast is obtained by summing up the probability-weighted losses across provinces.

Using the probability estimates of monsoon-season drought, the annual production loss for the northeast region is estimated to be 78,000 tons, which is about 1.2% of the mean output. Using the average rough rice price of $130 per ton, the value of annual production loss estimated this way is $10 million. The annual average loss at the aggregate level in northeast Thailand is thus relatively small. The effect of drought seems to be localized, with rice production not being affected throughout the northeast region simultaneously. The effect of drought on other crops (maize and soybean) was also investigated using the dummy variable model. However, none of the effects were statistically significant.

In terms of spatial distribution, the average annual production loss across provinces is up to 1.7%, 4.3%, and 8.3% of the mean annual output in Zones I, II, and III, respectively. Based on the annual production loss, the impact of drought on rice production is comparatively high in Chaiyaphum, moderate in Khon Kaen and Udon Thani, and low in other provinces.

Using a labor input of 60 person-days per ha in rice cultivation (Pandey and Velasco 2002) and average rice yield of 1.95 t $ha^{-1}$ in northeast Thailand, 31 person-days are required to produce 1 ton of rice. With drought causing an estimated 0.7 t of production loss during a drought year, the consequent employment loss is estimated to be around 20 million person-days.

## 4. Farm-level analysis

The major characteristics of rice production systems, household income structure, and farm-level impacts of drought are discussed in this section. The drought impacts are analyzed by comparing farming practices, crop yields, and net returns between "normal" and "drought" years. The results and discussions are based on farm household survey data.

### 4.1 Major characteristics of rice production systems and the household economy

General characteristics of sample households and their demographic features are presented in Table 5.11. Overall, the average household size is 5.0. Agriculture is the main occupation (73%) of the economically active population. The proportion of the population employed in agriculture is similar across all zones.

The average farm size is approximately 4 ha (Table 5.12). Farmers in the northeast are mostly owner-operators. Land leasing is not widely practiced. Overall, rice is the major crop, accounting for 58% of the cropped area, followed by upland field crops[5] (26%) and horticultural crops (7%). Rice accounts for the major share of the cropped area in Zones I and II, while the share of rice is below 50% in Zone III. Horticultural crops are also grown in all zones. In recent years, the government has promoted crop diversification by encouraging farmers to grow high-value upland and horticultural crops. Livestock such as cattle, buffaloes, and poultry are an integral part of the farming system. Despite increasing mechanization, cattle and buffaloes are still being used as draft power.

[5]Major upland field crops grown in the region are cassava, kenaf, sugarcane, soybean, and maize.

**Table 5.11. Demographic characteristics of sample households, northeast Thailand.**

| Household characteristics | Zone I | Zone II | Zone III | All zones |
|---|---|---|---|---|
| Household size (no.) | 5.0 | 5.3 | 4.8 | 5.0 |
| Average age of household head (years) | 52 | 53 | 52 | 52 |
| Average schooling of household head (no. of years) | 4.7 | 4.4 | 4.7 | 4.6 |
| Main occupation (%)[a] | | | | |
| Agriculture | 76 | 71 | 76 | 73 |
| Salaried job | 24 | 24 | 22 | 24 |
| Business | 0 | 5 | 2 | 3 |

[a]Defined for 16–60-years' age bracket group only. Some members may have multiple occupations.

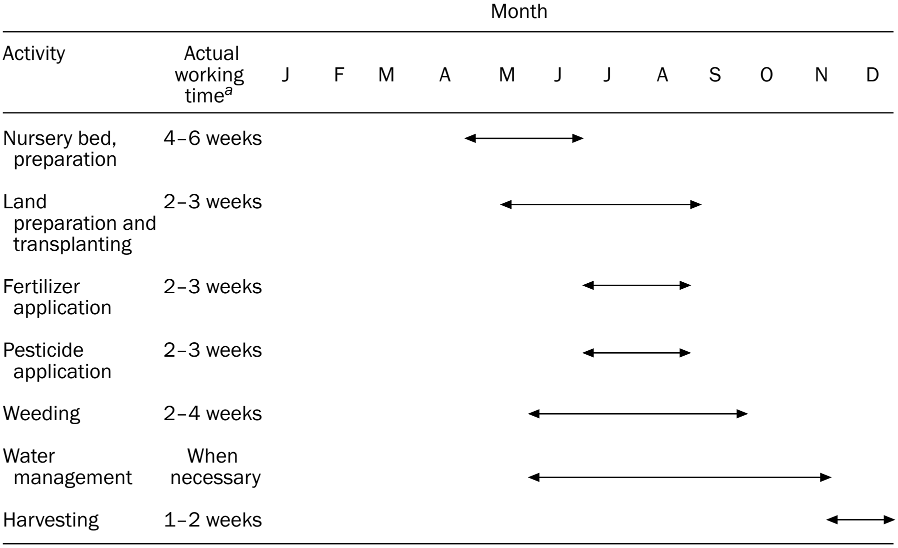
**Table 5.12. Farm size and land-use characteristics of sample households, northeast Thailand.**

| Land characteristics | Zone I | Zone II | Zone III | All zones |
|---|---|---|---|---|
| Farm size (ha)[a] | 3.5 | 3.7 | 4.3 | 3.9 |
| Number of parcels (no./household) | 2.3 | 2.4 | 2.8 | 2.5 |
| Tenure status (% of households) | | | | |
| Owner-operator | 90 | 87 | 83 | 86 |
| Owner-operator + tenant | 10 | 13 | 17 | 14 |
| Land-use characteristics (% area) | | | | |
| Rice | 73 | 68 | 44 | 58 |
| Upland crops[b] | 4 | 15 | 42 | 26 |
| Horticultural crops[c] | 8 | 6 | 7 | 7 |
| Perennial trees[d] | 2 | 2 | 0 | 1 |
| Pasture land | 9 | 5 | 4 | 5 |
| Fish pond | 3 | 2 | 2 | 2 |
| Others[e] | 1 | 2 | 1 | 1 |
| Total | 100 | 100 | 100 | 100 |

[a]Farm size does not include homestead, rented-out area, and mortgaged-out area. [b]Upland field crops include maize, cassava, kenaf, sugarcane, and others. [c]Horticultural crops include fruits and vegetables. [d]Perennial trees include bamboo, mulberry, eucalyptus, and rubber trees. [e]Others include integrated farming of cereals, upland field crops, horticultural corps, and livestock.

Rice is cultivated in both the wet and dry seasons. The wet season is the main rice-growing season. Wet-season rice is planted during early May to mid-August and harvested during mid-November to late December (Fig. 5.5). Dry-season rice is grown in limited irrigated areas during late November to late March.

Farmers practice both transplanting and direct-seeding methods for establishing rice. Upper terraces that do not hold much water are mostly direct-seeded, while the lower terraces are normally transplanted. During drought years when rainfall is either scanty or delayed, farmers opt for direct seeding even in lower terraces. Rice seedlings are normally kept in the nursery bed for 1 month and are subsequently transplanted when adequate rains have been received.




[a]Depending on farm size.

**Fig. 5.5. Wet-season rice farming activities and duration in northeast Thailand.**

A majority of the farmers grow glutinous varieties in Zones I and II but nonglutinous varieties in Zone III. RD6 is the most popular glutinous variety, while KDML105 is the most popular nonglutinous variety. Hom-sa-ngiam and Nang Yee in the glutinous category and Lueng Pratiew, RD15, Lueng, and Kao Lueng in the nonglutinous category are the other popular varieties grown in the region.

Land preparation is mostly mechanized. Locally blended fertilizers with an NPK composition of 16-16-8 and 16-20-0 are the most commonly used. The average application of inorganic fertilizer in rice is 80 kg $ha^{-1}$. The use of compost fertilizer, farmyard manure, and organic fertilizers is minimal. Similarly, the use of plant protection chemicals such as herbicides and insecticides is minimal. Harvesting is mostly done manually. Harvested rice is mechanically threshed and transported to the rice barn located in the homestead area, from where some farmers may sell it directly to traders.

The average rice yield for the northeast region is 2 t $ha^{-1}$. Rice yield is statistically significantly higher in Zones II and III than in Zone I (Table 5.13). Despite the high risk of drought, a higher average rice yield in Zone III is mainly attributed to good soil conditions (KKU-FORD Cropping Systems Project 1982).

Farmers incur cash costs in purchasing material inputs and labor. Material inputs are seeds, fertilizers, chemicals, and fuel. They also include service inputs such as hired tractors and threshing machinery. The labor cost is the payment to wage laborers. The "cash" inputs thus defined do not include inputs provided by the farm household. The

**Table 5.13. Rice yield and costs and returns of rice production, northeast Thailand.**

| Item | Zone I[a] | Zone II | Zone III | All zones |
|---|---|---|---|---|
| Rice yield (t $ha^{-1}$)[a] | 1.59a | 2.02b | 2.20b | 2.02 |
| Gross value of production (US$/ha)[b] | 210 | 270 | 300 | 270 |
| Cash cost (US$/ha) | 80 | 80 | 120 | 100 |
| Net return above cash cost (US$/ha) | 130 | 190 | 180 | 170 |

[a]Rice yield is statistically significant between a and b but not statistically significant between b and b. [b]A rice price of US$130 $ton^{-1}$ is used to estimate the gross value of production.

average total cash cost of rice production is $100 per ha (Table 5.13). The preharvest cost accounts for 61% of the total cash cost. The cost of chemical fertilizers is the highest among all material inputs and accounts for 22% of the total cash cost. Seeds and plant protection costs account for less than 5% of the total cash cost. The average net returns above cash cost are about $170 per ha. Of the three zones, the net return is highest in Zone II and lowest in Zone I. The difference in returns across the zones is driven mainly by yield differences.

Although rice used to be mostly kept for home consumption traditionally, it is now an important marketed product. On average, sale accounts for 21% and 54% of production for glutinous and nonglutinous rice, respectively. The proportion of glutinous and nonglutinous rice sold varies across the zones. The amount of glutinous rice sold in Zone I is only 15% compared with 71% for nonglutinous rice. This is because glutinous rice is preferred for home consumption in Zone I.

There are four major periods during the year when rice is sold. These periods generally coincide with loan due dates and the timing of major household and production expenditures. The largest quantity of rice is sold soon after harvest in December and a part of the proceeds is used to repay production loans received from local money lenders. The next lot of rice is sold in February, which is the time when loans obtained from the Bank for Agriculture and Agricultural Cooperatives (BAAC) become due. In May, some rice is sold again to meet the cost of children's school enrolments. Additional quantities of rice are sold in July and August to pay for the cash costs of land preparation and fertilizer for the next rice crop.

Farmer behavior concerning rice stock-keeping is changing over time. In the old days, farmers kept the rice stock not only for current year consumption but for the following years as well. This is a risk-coping mechanism for achieving food security over time. With the commercialization of rice farming, market-based strategies have increasingly substituted for storage of stock on the farm. Farmers increasingly sell most of their rice soon after harvest even though they may buy back some rice later in the year. Despite the economic advantages of such market-based strategies, some farmers may suffer during drought years if they dispose of most of their reduced production of rice early in the season to meet immediate credit obligations and are unable to purchase sufficient rice later due to income deficiencies.

**Table 5.14. Percentage decomposition of household income by income sources and income quartiles, northeast Thailand.**

| Source of income | Household income quartile | | | | All |
|---|---|---|---|---|---|
| | Bottom quartile | 26–50% | 50–75% | Top quartile | |
| Rice | 52 | 39 | 27 | 12 | 21 |
| Nonrice crops | 5 | 12 | 10 | 10 | 10 |
| Livestock | 9 | 11 | 17 | 9 | 11 |
| Farm wage | 8 | 10 | 3 | 7 | 7 |
| Nonfarm | 26 | 28 | 43 | 62 | 51 |
| Total income (US$) | 610 | 1,320 | 2,310 | 6,160 | 2,580 |

**Table 5.15. Percentage loss in rice area, yield, and production in a drought year compared with normal year, northeast Thailand.**

| Zone | Area | Yield | Production |
|---|---|---|---|
| I | 19 | 31 | 44 |
| II | 19 | 40 | 51 |
| III | 25 | 56 | 67 |
| All zones | 21 | 45 | 56 |

The average household income during a normal year is estimated to be $2,600. Agricultural income accounts for 49% of the total household income. The share of rice income is 21% of the total income. Upland field crops, livestock production, and farm wages are the other important sources of income. Off-farm employment constitutes 33% of the total income of households. The major source of off-farm income is employment in Bangkok and other cities. Income sources are more diversified in Zone III than in Zones I and II.

The income structure of farmers during normal years is also analyzed using distribution by income quartiles (Table 5.14). The average income of the bottom quartile is only 10% of that of the top quartile. This difference is accounted for mainly by nonfarm income. For the top quartile, nonfarm income accounts for almost 62% of the total income. Overall, the lower quartiles derive larger proportions of their income from the farm relative to the upper quartiles. The share of rice income in the total household income is above 50% for the bottom quartile. This share decreases with movement up the quartiles. Thus, rice as a source of income becomes less important as total income increases.

## 4.2 Farm- and household-level impact of drought

The overall loss in rice production during drought years is 56%. This arises from the loss in area and yield of 21% and 45%, respectively (Table 5.15). Both loss components are higher in Zone III than in the other zones. The low average rainfall and its

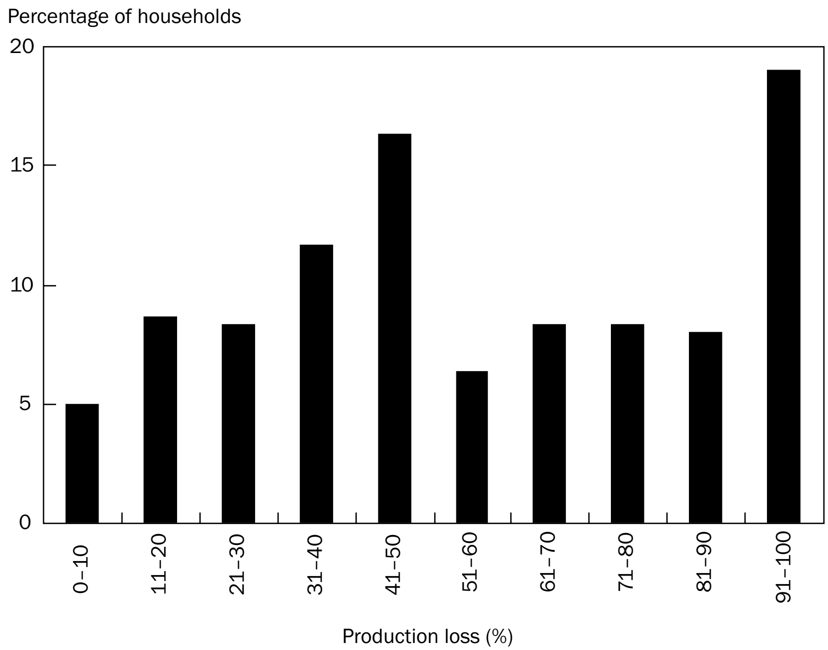



**Fig. 5.6. Percentage distribution of households by magnitude of rice production losses due to drought, northeast Thailand.**

highly variable temporal distribution relative to other zones (Table 5.6) are the main reasons for this relatively higher production loss in Zone III.

It is to be noted that although yield loss accounts for most of the production loss, the effect of area loss is not small. Farmers simply did not plant rice on 21% of their paddy land during drought years because of delayed and/or insufficient rains. Where rice was planted, yield decreased by 45%, resulting in an overall loss in production of 56%. This area instability is an important source of instability in production.

The frequency distribution of production losses is shown in Figure 5.6. The distribution is bi-modal, with 28% of the households suffering production losses of 30–50%. Almost 20% of the households lose over 90% of production. For those households that lose over 90% of rice output, the consequences of drought could be severe, especially if they also happen to be the poorer households. The differential impact of drought on different income groups is analyzed further later in this section.

Production costs including harvest during normal years average \$95 ha$^{-1}$ and drop to \$61 ha$^{-1}$ during drought years (Table 5.16). This reduction in cash costs is accounted for by the reduced costs of crop establishment and fertilizer. The overall average net returns above cash costs during a normal year are \$168 ha$^{-1}$, and this drops to \$85 ha$^{-1}$ during drought years. The relatively large absolute drop in yield in Zone III results in the lowest net returns above cash costs in this zone.

**Table 5.16. Costs and returns of rice production during normal and drought years, northeast Thailand.**

| Item | Zone I | | Zone II | | Zone III | | All zones | |
|---|---|---|---|---|---|---|---|---|
| | NY[a] | DY[a] | NY | DY | NY | DY | NY | DY |
| Rice yield (t ha$^{-1}$) | 1.59 | 1.10 | 2.02 | 1.22 | 2.20 | 0.97 | 2.02 | 1.12 |
| Gross value of production (US\$ ha$^{-1}$)[b] | 207 | 143 | 263 | 159 | 286 | 126 | 263 | 146 |
| Cash cost (US\$ ha$^{-1}$) | 79 | 47 | 81 | 57 | 124 | 69 | 95 | 61 |
| Net return above cash cost (US\$ ha$^{-1}$) | 128 | 96 | 182 | 102 | 162 | 57 | 168 | 85 |

[a]NY means a normal year and DY means a drought year. [b]A rice price of US\$130 ton$^{-1}$ is used to estimate the gross value of production.

**Table 5.17. Effect of drought on household (hh) income by zone, northeast Thailand.**

| Item | Zone I | Zone II | Zone III | Northeast |
|---|---|---|---|---|
| Average total income (US\$ hh$^{-1}$) | 2,456 | 2,678 | 2,516 | 2,583 |
| Average rice income (US\$ hh$^{-1}$) | 437 | 605 | 515 | 547 |
| Share of rice income in total income (%) | 18 | 23 | 20 | 21 |
| Rice income loss (%) | 41 | 49 | 66 | 54 |
| Effect of drought on total income through loss in rice income (%) | 7 | 11 | 14 | 12 |

During drought years, the overall drop in income from rice is 59%, with a range of 41–66% across zones (Table 5.17). As indicated earlier, the share of rice income in total household income during normal years is 18–23%. Given these values, the overall effect of losses in rice production due to drought on farmers' income is estimated to be 12%, with a range of 7–14%. The lower estimate applies to areas with diversified agriculture such as in Zone III, while the upper estimate applies to areas that are more dependent on rice income such as Zone II. As expected, the income effect of a drop in paddy production due to drought is less where farmers have more diversified agriculture.

A greater dependence of lower-quartile groups on farm income means (as indicated earlier) that they are likely to incur relatively higher income losses during drought years. To investigate this, the share of rice income of each quartile group during normal years and the loss in rice income during drought years are analyzed. The share of rice in total income decreases from lower to upper quartiles (Table 5.18). The bottom quartile derives over 50% of total income from rice, while the corresponding share for the top quartile is only 12%. Multiplying this value by the percentage drop in rice income during drought years provides an estimate of the proportionate loss in total income resulting from drought. The estimates indicate that the bottom quartile loses

**Table 5.18. Effect of losses in rice income on total household (hh) income, by income quartile, northeast Thailand.**

| Item | Income quartile | | | | |
|---|---|---|---|---|---|
| | Bottom | 26–50% | 50–75% | Top | All |
| Average total income during normal year (US$ $hh^{-1}$) | 610 | 1,320 | 2,310 | 6,160 | 2,580 |
| Average rice income during normal year (US$ $hh^{-1}$) | 320 | 520 | 630 | 710 | 550 |
| Share of rice income in total income during a normal year (%) | 52 | 39 | 27 | 12 | 21 |
| Rice income loss during a drought year (%) | 59 | 52 | 53 | 55 | 54 |
| Share of loss in rice income in total income loss (%) | 31 | 20 | 14 | 7 | 12 |

31% of total income during drought years (assuming that all other sources of income remain unaffected), while the corresponding loss for the top quartiles is only 7%. This clearly indicates that poorer groups suffer a higher proportionate loss in total income as a result of a drop in rice production during drought years. This differential impact of drought across income groups has not been adequately considered when the government designs drought alleviation programs.

## 4.3 Farmers' coping strategies

Farmers who are exposed to drought risk practice various strategies to ensure their survival despite all odds. Over a long period of time, some of these strategies are incorporated into the nature of the farming system and are often not easily identifiable as risk-coping strategies. Others are employed only under certain risky situations and are easier to identify as responses to risk. This section presents various drought-coping strategies used by farmers in northeast Thailand based on group discussions and case studies.

Based on the case studies and focus group discussions with farmers, the most commonly used adjustments in rice production practices during drought years are as follows:

- Allocating more area to short-duration varieties.
- Switching to traditional varieties such as Nok Krachab, which is considered to be more drought-resistant.
- Reducing the planted area of commercial varieties such as KDML 105 and expanding the area of varieties that are used for home consumption.
- Increasing plant density in transplanted rice.
- Switching from transplanting to direct seeding.
- Purchasing rice seedlings from neighboring districts when rains are delayed.

- Constructing farm ponds to supplement water during dry spells. However, if the dry spell persists for a long time, the farm ponds will be unable to solve the problem.
- Using a pump to irrigate rice in areas where the water table is not deep.
- Substituting rice with upland crops such as sugarcane and cassava.

Reducing cash expenditures on inputs in rice production through adjustments in labor input is an important drought-coping mechanism. There is some savings in cash cost of labor due to shifts in crop establishment method from transplanting to direct seeding among some farmers. In addition to the generally labor-saving nature of direct seeding, the associated cash cost for direct seeding is generally low since family labor is used mostly for direct seeding. During drought years, farmers attempt to reduce cash costs of production by employing more family labor in place of hired labor. This is partly achieved by changing the crop establishment method.

The decrease in rice production during drought years translates into a reduction in the quantity sold. Sample households reduce the sale of rice during drought years by 36–82% relative to a normal year. However, the amount available for consumption drops by 46% despite this downward adjustment in sale. More households engage in purchasing rice during drought years to meet this shortfall. The number of rice-purchasing households increases from 14% in a normal year to 38% in a drought year. Farm survey data indicate that the price rise during drought years is 3–5%. This rise in price, although a relatively small one, will nevertheless erode purchasing power, especially that of poorer farmers who may have to buy rice at a higher price. Some of these farmers are likely to suffer a consumption shortfall.

In addition to the above adjustments in rice production practices, other adjustments in household economic activities are as follows:

- Reducing or stopping rice sales to augment supply for home consumption.
- Selling more buffaloes and cattle in drought years to meet cash needs. This is practiced more when drought occurs during consecutive years. However, livestock are also sold in nondrought years on a regular basis as this has become an important source of farm income in northeast Thailand. For livestock raised on the farm, crop residues are an important component of the feed. Farmers reported that farm-raised livestock are adversely affected in drought years due to a lack of sufficient crop residues.
- Working off-farm to earn subsidiary income to buy rice for consumption. To earn extra income, younger people generally move to Bangkok while older people seek employment as construction workers in provincial towns.
- Engaging in some other nonfarm enterprise, such as weaving, clothes making, and other kinds of handicraft.

## 5. Drought mitigation policies and institutional setup

This section provides an overview of policies and institutional setup for drought management in Thailand in general and in northeast Thailand in particular. A detailed assessment of the success and failure of government policy interventions on fighting drought is made in the first part and institutional arrangements and responses to drought mitigation are analyzed in the latter part. The discussion is primarily based on secondary data.

The government of Thailand has adopted a two-pronged strategy for drought mitigation. The first involves a long-term mitigation strategy comprising water resources development, improvements in agricultural technologies, and policy support for farm enterprise diversification for efficient risk management. The second involves a short-term strategy to provide relief to drought-affected farmers.

Although the impact of drought on agricultural production is an important issue, public concern about the water supply for urban and industrial use is an important factor driving the agenda. The water supply in the Central Plains, where Bangkok, with a population of over 8 million, is located, depends entirely on the Bhumibol and Sirikit dams. These dams also supply water for irrigated rice production in the intensive rice bowls of the Central Plains and for electrical power generation. Lowering of the water level in these dams due to low rainfall or reduced flow naturally becomes a major public concern. The major droughts in the past 15 years, such as in 1993, 1997, 2002, and 2004, all led to a drastic drop in water level in these dams. The allocation of water from these dams to alternative uses becomes an important issue in drought years. Similarly, the supply of drinking water to rural households affected by drought in other parts of the country is an important consideration. Although an important policy issue, reducing the impact of drought on agricultural production often takes a secondary place in policy discussions. Hence, it is important to view current policies and programs in this broader context.

## 5.1 Long-term drought mitigation policies

The major long-term policies for drought mitigation reviewed by Suwanabatr and Mekhora (2002) can be grouped into four major categories: water resource development, improved agricultural technologies, rural income diversification, and drought mapping and forecasting.

*Water resource development.* This encompasses a wide range of activities such as irrigation systems development, more efficient use of irrigation water, and general watershed development through improved forest management and reforestation. Various policies and initiatives implemented by the government of Thailand in this regard have been discussed by Suwanabatr and Mekhora (2002).

As rice production mainly takes place under rainfed conditions, public investment in irrigation systems is vital to reduce the risk of water shortages and to stabilize rice production. The Royal Irrigation Department is the major government agency involved in overall irrigation systems development in the country. This department is in charge of developing large, medium, and small water reservoirs for irrigation, electricity generation, and consumption purposes. In addition, minor irrigation schemes based on farm ponds are also being developed. The development of farm ponds has also received support from the king of Thailand. A farm-pond development project was implemented in 1993-96 with a total budget of $107 million. Farm ponds have been constructed with both support from the government and also using farmers' own funds. Although anecdotal evidence indicates a positive impact of farm ponds, their overall impact on drought mitigation is yet to be fully evaluated.

Policies for improving watershed management are being implemented for broader benefits than just for drought mitigation. This is also tied up with overall forest management policy, since most of the mountainous catchment areas are forested. Several projects for reforestation and afforestation have been implemented and forest management guidelines have been drawn up. Recently, a policy initiative for water resource development was implemented. In a cabinet meeting in March 2005, the government of Thailand approved $5.3 billion to implement a master plan for water resource development over the next four years. The master plan covers all aspects of water resource development.

*Technology development.* Major efforts are being made to develop improved technologies for raising overall agricultural productivity in water-limited conditions. Through the support of international agencies such as the International Rice Research Institute and the Rockefeller Foundation, Thai rice researchers are actively engaged in developing rice technologies that perform well even during droughts. This effort includes the development of drought-tolerant rice varieties and improved management of rice (establishment, fertilization, and weed control). Important progress is being made in developing drought-tolerant varieties (Fukai and Cooper 2001, Fischer et al 2003, Jongdee et al 2004). The development of the modern science of biotechnology has helped to make big strides in rice breeding in Thailand. Similarly, strategies for improving moisture-use efficiency through improved crop husbandry have been identified (Wade 1999).

*Rural income diversification.* Several policies and projects for rural adjustments have been implemented in Thailand for poverty reduction. These activities have a direct impact on drought mitigation also. Rural job creation is one policy initiative that started during the late 1970s. This basically involved public works such as construction of rural roads, public ponds, and various public utilities. These public works were implemented in drought-affected areas for income generation. Recently, the project One-Tambon One-Product (OTOP) was introduced to promote local crafts and home industry.

Regarding farm income, Thailand has achieved, to a great extent, diversification from monoculture rice to many commercial crops such as cassava, maize, sugarcane, and a wide range of fruit trees. A policy on diversification was implemented during 1994-2001 through the Agricultural Restructuring Project (ARC), which had a total budget of $49 million. A total of 592,000 farmers participated in this project. Agricultural credits were provided to farmers to encourage a shift from paddy to other crops in marginal drought-prone areas.

*Mapping and forecasting.* Remote-sensing and GIS-based approaches are being used to better map out drought-affected areas. Several provinces throughout the country have been mapped as being vulnerable to drought (Suwanabatr and Mekhora 2002). Similarly, climatological models are being used to develop early-warning systems.

Drought forecasting is being done by the Department of Meteorology, with cooperation from the Royal Irrigation Department. The Office for Natural Calamity Mitigation for Farmers within the Ministry of Agriculture and Cooperatives was established in 1998 as the overall coordinating body for all types of natural calamities. This office plays an important role in drought forecasting and preparedness.

## 5.2 Short-term drought mitigation strategies (relief)

Short-term drought mitigation strategies (relief) are provided during drought years only. Activities range from artificial rainmaking to the provision of direct relief in the form of agricultural inputs and other support to rural households.

*Royal project for artificial rainmaking.* Artificial rainmaking is a direct attempt by the King of Thailand to address the drought problem. The concept is to spray some nontoxic chemicals for seeding clouds. The project started as early as 1970. It was first initiated by His Majesty the King but later was institutionalized as the Bureau of Royal Project for Rainmaking and Agricultural Aircrafts within the Ministry of Agriculture and Cooperatives. Cloud-seeding is carried out upon the request of the provincial administration affected by drought. The success of the operation is, however, dependent on the existing clouds. The cloud-seeding project has developed effectively over time. It now covers all major areas of the country. Recognizing this need, the budget of the Bureau was increased from $18 million in 2000 to $20 million in 2003.

*Extending the period of debt payment.* Most farmers in Thailand obtain agricultural credit from the Bank for Agriculture and Agricultural Cooperatives (BAAC). The repayment period is extended by BAAC during drought years at no additional cost to affected farmers.

*Minimization of dry-season cropping.* Dry-season cropping of rice in the intensive rice bowls of the Central Plains consumes a lot of water. During drought years, the government actively discourages farmers from planting rice through various measures ranging from an outright ban on rice planting to various incentive-based measures. Recommendations to grow upland crops such as soybeans, peanuts, and mungbeans are made and support to farmers who switch to such upland crops is also provided. However, such policies have not worked well in the past mainly because rice production in the Central Plains is highly profitable and the cost of irrigation water is very low. There is an increasing realization in policy circles that a water-pricing policy that adequately reflects the scarcity value of water is needed to promote efficient use of irrigation.

*Provision of drinking water.* A shortage in drinking water occurs frequently during drought years. Farmers' usual strategy for dealing with shortages is to collect and store rainwater in large clay jars. The government is completing this traditional strategy through water resource development, the establishment of a rural water supply system, and emergency distribution of water. The coverage of such distribution programs was often limited, however, and the response tended to be somewhat slow.

*Provision of relief.* The government provides various farm inputs such as seed and fertilizer to drought-affected farmers to help them during the subsequent year. This compensation is provided only to farmers who planted a crop but were unable to obtain an adequate harvest because of drought. Those who were not able to plant are not covered in this scheme. The basic idea behind such a policy seems to be to compensate farmers who have lost seeds and inputs.

Estimates of the farm area affected are provided to the MOAC by the district agricultural offices that collect information on area damaged on a regular basis. For example, drought-affected farmers in Dan Khun Tot District of Nakhon Ratchasima in 2001 were given rice seeds, chemical fertilizer, and hybrid maize and groundnut seeds. The total value of this assistance was $0.14 million (Office of Agriculture of Dan Khun Tot District 2003). Since 2004, the system was changed from giving assistance in kind to cash for a more efficient distribution of assistance. The new system also decentralized the assistance scheme to the provincial offices by giving them more authority in disbursing the budget to assist farmers (Jirawat 2005). Similarly, an information technology (IT) center of agricultural information has been established within the DOAE to make information on village-level damage due to drought available to policymakers in a rapid and timely manner.

The Department of Disaster Prevention and Mitigation under the Ministry of Interior is responsible for providing relief to drought-affected farmers. The most common form of assistance is seed distribution by government agencies. Although this is helpful when done in a timely manner, farmers who have already left for other jobs out of the area by the time the seeds are distributed do not benefit from such distributions. Most farmers did not receive any government drought relief programs during drought years. Likewise, relief assistance from nongovernmental organizations is virtually nil.

There are three levels of government administrative organizations for drought mitigation: the national level, the ministerial level, and the local level (Fig. 5.7). (i) The National Committee for Civil Disaster Prevention and Mitigation and the National Committee for Drought Prevention and Mitigation are the two national-level agencies tasked with the overall coordination of the various activities related to disaster and drought management at the national level. (ii) The ministerial committee coordinates the work of different agencies within the ministry. (iii) The local-level implementing agencies at the district or province level implement the programs of the government.

With the exception of the Meteorology Department, most of the national agencies involved in planning and implementing drought mitigation programs are within the Ministry of Agriculture and Cooperatives. In addition, specific programs to assist affected farmers are implemented by the Department of Cooperative Promotion, Department of Royal Rainmaking and Agricultural Aviation, Department of Land Development, and Agricultural Land Reform Office. The programs are implemented through the provincial and district governments, which have their own centers for drought mitigation and coordination.

The process of relief provision starts with a survey of an affected area by the village headmen in cooperation with the head of the Tambon Agricultural Technology Transfer Center (TATTC). The estimates of affected area are reported to the district agricultural officer, who then forwards a consolidated report to the District Natural

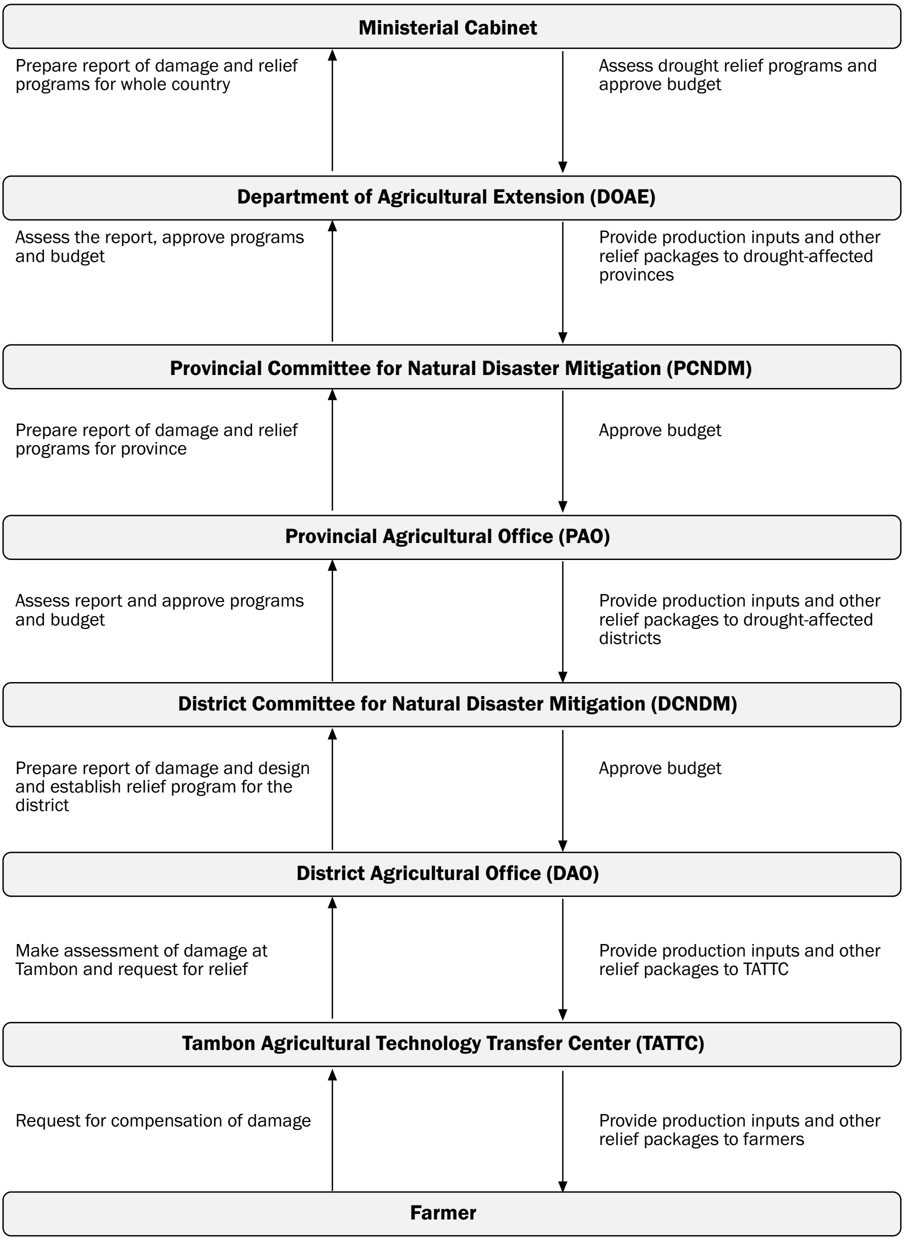



**Fig. 5.7. Organizational structure showing the system of drought relief for farmers within the Department of Agricultural Extension.**

Hazard Mitigation Committee for approval of drought relief. A change in policy from providing relief in kind (seed, fertilizer, etc.) to cash occurred in 2001 to enable faster distribution of relief to the affected households (OAE 2003).

The evaluation of a mitigation program for natural calamities of the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives (OAE 2003), reported that (i) despite good coordination among different government agencies, the assistance program lacked continuity and focus due to the absence of a clear master plan; (ii) often, the mitigation programs were mainly relief-oriented and were unable to achieve long-term protection from drought; (iii) despite rapid action from the local government, there were delays in swift mobilization of assistance at the higher level of government. In addition, the funds approved were often only a fraction of the request made. This limited the coverage and efficiency of the program at the village level.

## 6. Conclusions and recommendations

Drought is a recurrent phenomenon that affects the agricultural production of Thailand. Major droughts in recent years occurred in 1997, 1998, and 2004. The losses in agricultural GDP due to drought in these years were on the order of 1–3%. Although the share of agriculture in total GDP of Thailand is only 10%, the overall rural economy is adversely affected because of the knock-on effects of major droughts.

Drought probability in northeast Thailand is estimated to be 9–20%. The southwestern area (i.e., Zone III consisting of Chaiyaphum and Nakhon Ratchasima provinces) is the most drought-prone. During the rice-growing period, both early- and late-season droughts occur, with the probability of late-season drought being higher (20%) than that of early-season drought (9%).

Drought in northeast Thailand is, however, not highly covariate. This means that drought events tend to be somewhat localized. Such localized droughts are, naturally, less problematic than a covariate (or widespread) drought. Aggregate production in such situations tends to be quite stable, even though some areas may suffer drastic production losses. In fact, the analysis of temporal variability of rice area, yield, and production for northeast Thailand shows a high degree of stability around the trend as measured by the coefficients of variation.

At the provincial level, losses in rice production during drought years are estimated to be 8–55% of the average production. The annual production loss due to drought, estimated by considering the probability of drought occurrence, for the whole of northeast Thailand is estimated to be 1.2%. This aggregate loss is relatively small compared with losses to drought in other rainfed areas such as in eastern India, where the estimated loss is around 8%.

Although production losses at the aggregate levels are small, the impact at the household level is substantial. Affected households suffer a 56% loss in production, on average, during drought years. This loss in production results from both a loss in area (19–25%) and loss in yield (31–56%). Although yield loss is the main factor driving production losses, the effect of loss in area is also substantial.

Total household income drops by 34–39% during drought years. Rice accounts for an 11% drop in income on average. The effect of losses in rice production is higher among poorer farmers, who derive almost 50% of their income from rice production. A drop in rice income accounts for nearly a 30% drop in their total income. Thus, improved technologies to reduce losses in rice production will help lower-income farmers more than higher-income farmers.

Farmers in Thailand deploy a range of mechanisms to cope with drought. These include careful adjustments in rice varieties, planting methods, and input use. Farmers change rice varieties (when drought is early), switch from transplanting to direct seeding, and reduce input use in response to drought. Such adjustments are naturally possible when drought occurs early in the growing season. As the season progresses, the opportunities for making such crop management adjustments decrease.

When drought results in a severe loss in income, an important coping mechanism deployed by Thai farmers is to migrate to cities in search of nonfarm employment. The growth of the nonfarm sector and the availability of jobs for unskilled labor in cities such as Bangkok have helped farmers augment their income during drought years. This is one of the reasons why Thai farmers do not seem to suffer consumption losses despite substantial losses in farm income. In addition, they also use other strategies such as obtaining consumption loans and using their savings to cope with drought. In addition, the government provides some relief to affected households.

Drought and other climatic risks are intrinsic to agricultural production. Hence, strategies and policies for effective management of drought should be an integral part of the broader rural development policy. Policies that promote income growth and enterprise diversification in rural areas, which facilitate more efficient management of various risks, are potential instruments for drought mitigation. These generic rural development policies, including those for water resource development, were reviewed in the previous chapter. Further streamlining and effective implementation of these policies will provide for the development of a more flexible and resilient agricultural production system that is able to diffuse and dissipate various risks efficiently.

It is important to recognize that the overall temporal variability in rice production in northeast Thailand is generally low. Although somewhat covariate, droughts do not seem to occur in all provinces in the northeast at the same time. Production is not necessarily affected severely in all provinces even when drought, as indicated by rainfall deficit, occurs over a wider area. Also, as found in this study, farmers do not seem to suffer a consumption shortfall as a result of drought. Thus, stabilization of national food production cannot be the primary rationale for drought mitigation. Instead, convincing rationales for drought mitigation are to reduce the adverse impact of drought on rural poverty, reduce the economic cost of adjustments to drought incurred by farmers, and minimize the impact on exports of rice. The empirical findings of the study clearly indicate that low-income farmers lose the largest share of income because of a drought-induced drop in rice production.

What policy measures will be most effective in addressing these problems? Obviously, improved agricultural technologies have important roles to play. Rice varieties that are tolerant of drought will help reduce yield loss. The opportunities for developing such varieties are well documented (Fukai and Cooper 2001, Jongdee et al 2004) and important scientific progress is being made on this front (Atlin et al 2006). The results of this study indicate that production is affected not only by losses in yield but also by losses in area. Early-season drought results in a contraction in rice area planted as well as crop failure in areas that were planted very late. Thus, improved rice varieties that perform well even when planted late could help reduce income loss so that farmers could better cope with drought. More work is needed on this aspect of varietal development as the current emphasis is mainly on yield stabilization.

In addition to varietal development, the success of a crop depends on suitable management. This includes proper establishment, fertilization, and weed control. The escalating cost of farm labor has led to an increasing shift toward direct seeding of rice in northeast Thailand (Pandey and Velasco 2002). In addition to this long-term trend, farmers expand direct-seeded area in drought years. Thus, technologies that raise the productivity of direct-seeded rice can help farmers cope with drought better. One of the major problems with direct-seeded rice is poor stand establishment. Improvements in technologies for land preparation and seeding for achieving uniform and good establishment of rice are needed. Similarly, high weed infestation is a serious problem with direct-seeded rice. Suitable technologies are also needed for effective weed management in direct-seeded rice. Although these individual component technologies can contribute on their own toward better management of direct-seeded rice, a package of complementary practices is needed for achieving synergy. A research program centered on direct seeding can help achieve such synergy. Current efforts in this area need to be strengthened.

In rainfed areas, small farm ponds can provide life-saving irrigation to crops affected by moisture stress. Through the Royal project, important progress has been made in expanding this technology (for details, see Section 5.2). Despite the positive contribution of these ponds to farm productivity, a difficulty is that water availability in these small farm ponds tends to be highly covariate with rainfall. Water storage in such ponds tends to be low during drought years. Farm ponds, hence, may not be very useful in providing irrigation to rice, which is a highly water-consuming crop. Instead, limited water from such ponds could be used for growing high-value crops such as fruits and vegetables, and for aquaculture. By enhancing farm income, these farm ponds can play an important but indirect role in helping farmers cope with drought better. Research and policy support are needed to identify and promote water-efficient crop and livestock production for income generation.

Some suggestions regarding relief efforts are in order. The government of Thailand has always provided relief support to farmers during drought years. Despite the establishment of various monitoring mechanisms to identify drought-affected areas, the relief is often poorly targeted and its quantity is too small or too late. Low-income farmers who are most adversely affected by drought do not always get their due share of the relief. Indicators of household vulnerability to drought need to be established to both identify vulnerable households and effectively target any relief to such households. This is an important area that needs careful assessment by the policymakers and institutions involved.

For better preparedness to deal with drought, the importance of early-warning systems cannot be overemphasized. Prediction of drought based on El Niño and local climatic factors is now scientifically quite advanced. Although such predictions are used routinely by various government departments for planning, such information is not yet made available in a timely manner and in a form that could assist farmers in making better decisions regarding the choice of crops to grow and management plans to follow. Lessons from countries such as Australia, which have now developed mechanisms to use weather predictions to improve farm management decisions, could be potentially useful in this regard.

## References


Adulavidhya K. 1979. Socioeconomic aspects of rainfed rice production in northeast Thailand. In: Rainfed lowland rice: selected papers from the 1978 International Rice Research Conference. Manila (Philippines): International Rice Research Institute. p 315-325.

Atlin GN, Lafitte HR, Tao D, Laza M, Amante M, Courtois B. 2006. Developing rice cultivars for high-fertility upland systems in the Asian tropics. Field Crops Res. 97:43-52.

Bank of Thailand. 2005. The inflation report. January 2005. Bangkok (Thailand): The Bank of Thailand. 97 p.

Ding S, Pandey S, Chen C, Bhandari H. 2005. Drought and rice farmers' coping mechanisms in the rice production systems of Southern China. A final research report submitted to the Rockefeller Foundation. Department of Agricultural Economics, Huazhong Agricultural University. Hubei (China): Huazhong Agricultural University.

Fischer KS, Lafitte R, Fukai S, Atlin G, Hardy B, editors. 2003. Breeding rice for drought-prone environments. Los Baños (Philippines): International Rice Research Institute. 98 p.

Fukai S, Cooper M. 1995. Development of drought-resistant cultivars using physio-morphological traits in rice. Field Crops Res. 40:67-86.

Fukai S, Cooper M. 2001. Development of drought resistant cultivars for rainfed lowland rice: experience from northeast Thailand and surrounding areas. Proceedings of the International Conference on the Impact of Agricultural Research for Development in Southeast Asia, 24-26 October 2000. Phnom Penh (Cambodia): CARDI. p 185-194.

Jirawat P. 2005. Data system and drought mitigation for farmers. A paper presented in the Seminar on New Dimensions for Drought Mitigation for Farmers in Northeast Thailand, 26 January 2005, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand.

Jongdee B, Pantuwan G, Fukai S, Fischer K. 2004. Improving drought tolerance in rainfed lowland rice: an example from Thailand. New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress, 26 Sept.-1 Oct. 2004, Brisbane, Australia.

KKU-FORD Cropping Systems Project. 1982. An agroecosystem analysis of northeast Thailand. Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand.

KRC (Kasikorn Research Institute). 2004. Drought in 2004: advance preparedness. An executive summary on current issues. Kasikorn Research Center Co., Ltd. Bangkok (Thailand): KRC.

Kupkanchanakul T. 2000. Bridging the rice yield gap in Thailand. In: Papademetiou MK, Dent FJ, Hearth EH, editors. Bridging the rice yield gap in the Asia-Pacific region. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific (RAP). Bangkok (Thailand): FAO/RAP.

Ministry of Interior. 2005. Disaster prevention and mitigation: the country report of Thailand 2005. Research and International Cooperation Bureau, Department of Disaster Prevention and Mitigation. Bangkok (Thailand): The Ministry of Interior. Online at www.disaster.go.th.

MOAC (Ministry of Agriculture and Cooperatives). 2003. Evaluation of relief service to farmers who are affected by natural calamities. Office of Agricultural Economics. Bangkok (Thailand): MOAC.

Mongkolsawat C, Thirangoon P, Suwanwerakamtorn R, Karladee N, Paiboonsak S, Champathet P. 2001. An evaluation of drought risk area in northeast Thailand using remotely sensed data and GIS. Asian J. Geoinformatics 1(4):33-43.

OAE (Office of Agricultural Economics). 2003. Evaluation of the assistance to farmers under the relief program from natural calamity—final report. The Office of Agricultural Economics. Bangkok (Thailand): Ministry of Agriculture and Cooperatives. Online at www.oae.go.th.

OAE (Office of Agricultural Economics). 2004. Agricultural statistics of Thailand crop year 2003/04. Office of Agricultural Economics. Bangkok (Thailand): Ministry of Agriculture and Cooperatives. Online at www.oae.go.th.

Office of Agriculture of Dan Khun Tot District. 2003. Information from interview of the Dan Khun Tot Agricultural District Officer on 19 March 2003.

Pandey S, Behura DD, Villano R, Naik D. 2000. Economic costs of drought and farmers' coping mechanisms: a study of rainfed rice systems in eastern India. IRRI Discussion Paper Series 39. Los Baños (Philippines): International Rice Research Institute. 35 p.

Pandey S, Velasco L. 2002. Economics of direct seeding in Asia: patterns of adoption and research priorities. In: Pandey S, Mortimer M, Wade L, Tuong TP, Lopez K, Hardy B, editors. Direct seeding: research strategies and opportunities. Los Baños (Philippines): International Rice Research Institute. p 3-14.

Reuters. 2005. Asian drought affects millions, hits crops, exports. Reuters News Service, 7 March 2005. Bangkok (Thailand). Cited in Planet Ark: The world environmental news. Online at www.planetark.com/dailynewsstory.cfm, accessed in July 2005.

Steyaert LT, Rao AV, Todorov AV. 1981. Agroclimatic assessment methods for drought/flood strategies in South and Southeast Asia. Washington, D.C. (USA): United States Agency for International Development.

Suwanabatr B, Mekhora T. 2002. Stabilization of upland agriculture under El Niño-induced climatic risk: impact assessment and mitigation measures in Thailand. CGPRT Center Working Paper No. 63. Bogor (Indonesia): The Regional Co-ordination Center for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT Center). 46 p.

TDRI (Thailand Development and Research Institute). 1994. Thailand's drought crisis. TDRI Quart. Rev. 9(1):28-29.

TFRC (Thai Farmers Research Bank Company). 1998. Warning of drought: an executive summary on current issues. Bangkok (Thailand): Thai Farmers Research Bank Co. Ltd.

TFRC (Thai Farmers Research Bank Company). 1999. The drought crisis: another problem for agriculture in 1999. An executive summary on current issues. Bangkok (Thailand): Thai Farmers Research Bank Co. Ltd.

TFRC (Thai Farmers Research Bank Company). 2002. Drought crisis: impacts on 2002's agricultural outputs. An executive summary on current issues. Bangkok (Thailand): Thai Farmers Research Bank Co. Ltd.

Wade LJ. 1999. Critical characteristics of rainfed rice environments and implications for rice improvement. In: Ito O, O'Toole J, Hardy B, editors. Proceedings of the Workshop on Genetic Improvement of Rice for Water-Limited Environments, 1-3 December 1998, Los Baños, Philippines. Los Baños (Philippines): International Rice Research Institute. p 1-10.

## Notes

*Authors' addresses:* P. Prapertchob, Department of Agricultural Economics, Khon Kaen University, 123 Mitraparb Highway, Khon Kaen 40002, Thailand; H. Bhandari, Social Sciences Division, International Rice Research Institute, currently with Japan International Research Center for Agricultural Sciences, 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan; S. Pandey, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines.
*Acknowledgments:* This research was supported by a grant from the Rockefeller Foundation. We are grateful to Dr. John O'Toole, then the associate director of the Foundation (Thailand), for his encouragement and support. Thanks are also due to Khon Kaen University management for administrative support. We thank the Department of Meteorology for providing rainfall data, and the Department of Agriculture and Department of Agricultural Extension of the Ministry of Agriculture and Cooperatives for giving access to various national, provincial, and local information. Last but not least is the cooperation from fellow farmers who kindly gave us their time for interviews and provided valuable information.

CHAPTER 6

# Economic costs of drought and rice farmers' drought-coping mechanisms in southern China

S. Ding, C. Chen, H. Bhandari, and S. Pandey

## 1. Introduction

Agricultural production is one of the major economic activities in China. The share of agricultural employment has remained at 50% of the overall employment despite the decrease in the share of agriculture in GDP from 32% in 1981 to 15% in 2003.

Because of the large and rapidly growing population, food security has long been a crucial issue in China (Brown 1994). Despite the increase in food production during the past decades, food security is still a concern. In recent decades, grain area decreased from 117 million ha in 1980 to 99 million ha in 2003. A large number of people, living in marginalized rural areas such as mountainous or resource-poor areas, are still suffering from a food shortage. Food insecurity, thus, will remain as an important problem in the coming decade. Among others, drought is an important cause of food insecurity.

Drought is one of the major natural disasters in China. Some 1,056 severe drought events were recorded from 206 BC to AD 1949 (Jun and Chen 2001, Li 1999). Continuous drought in 1628-41 is considered to have accelerated the decline of the Ming Dynasty. Twenty-nine drought events of moderate to severe intensity occurred from 1950 to 2004. Drought affected different parts of the country every year during 2000-05.

The published statistical data indicate that the annual "drought-covered" and "drought-affected"[1] area in China during 1978-2004 averaged 28 million ha and 14 million ha, respectively (Fig. 6.1). During 2000-05, drought affected production in different parts of the country almost every year (Table 6.1). The direct economic impact of drought is estimated to be 0.5% to 3.3% of agricultural sector GDP.

Rice is the main staple food grain in China. About 60% of the population lives on rice (Zhu 2000). During the triennium 2001-03, rice accounted for 18% of total sown area, 27% of grain-sown area, and 38% of the total grain output. Drought is one of the major constraints to rice production (ACCA21 1994, Lin and Shen 1996,

[1]"Drought-covered" refers to the area that experienced drought, while "drought-affected" refers to the area with a production loss of at least 30%. It is to be noted that occurrence of drought does not necessarily mean that a crop will be damaged.

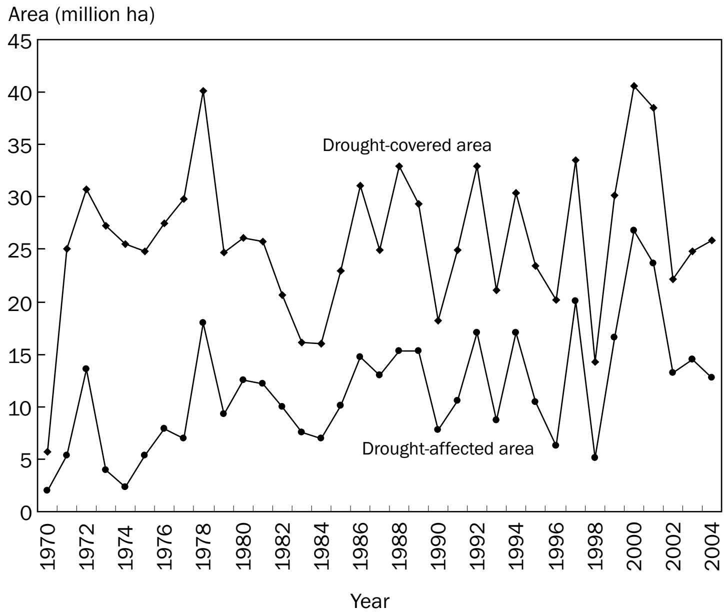



**Fig. 6.1. Drought-covered and drought-affected area, China, 1970-2004.**

Dey and Upadhyaya 1996, Li 2000, Zhu 2000). Although rice production in China is mostly irrigated, the increasing shortage of water for rice production is a major concern (Lohmar et al 2003, Rosegrant and Cai 2003, Yuanhua et al 2003, NDRC 2005). The average loss in rice yield due to drought has been estimated to be 3–5% of mean output (Dey and Upadhyaya 1996, Lin and Shen 1996).

The frequency of occurrence and consequent huge economic losses have put drought issues in the forefront of the policy agenda in China (MWR 2004). The government has been spending millions of dollars every year for drought relief and drought mitigation. For example, the government spent $100 million in 2000 (China Daily 2000/06/04), $363 million in 2001 (China Daily 2001/06/21), $420 million in 2002 (China Daily 2002/05/09), and $107 million in 2003 (China Daily 2004/07/26, MWR 2004) for drought mitigation and relief. In addition, the government also allocated an additional $48 billion for 2002-07 to develop water resources for drought mitigation (China Daily 2001/12/21, 2002/02/21).

The overall objective of this study is to estimate the economic costs of drought and to investigate rice farmers' drought-coping strategies in southern China. The specific objectives of the study are as follows:

1. To understand the nature and magnitude of drought risk in drought-prone rice-growing areas of southern China,
2. To estimate the economic costs of drought at the aggregate level,

**Table 6.1. Impact of recent drought in China.**

| Drought year | Affected people (million) | Affected area (million ha) | Crop area without harvest (million ha) | Affected livestock (million head) | Direct economic losses (billion US$)[j] | Affected provinces[k] |
|---|---|---|---|---|---|---|
| 1997[a] | 40 | 20 | 4.0 | 8.5 | 4.8 (2.9%) | Heilongjiang, Jilin, Liaoning, Inner Mongolia, Gansu, Ningxia, Shaanxi, Shanxi, Hebei, Shandong, Jiangsu, Anhui, Henan, Hubei, and Sichuan (56%). |
| 1999[b] | 22 | 17 | 3.9 | 19 | 4.3 (2.5%) | Liaoning, Inner Mongolia, Gansu, Qinghai, Ningxia, Shaanxi, Shanxi, Hebei, Shandong, Fujian, Hunan, Guangdong, Guagxi, Guizhou, and Yunnan (56%). |
| 2000[c] | 22 | 27 | 7.9 | 17 | 1.1 (0.6%) | Heilongjiang, Jilin, Liaoning, Hebei, Inner Mongolia, Gansu, Ningxia, Shanxi, Shandong, Jiangsu, Henan, Shaanxi, Sichuan, and Anhui (52%). |
| 2001[d] | 44 | 24 | 6.4 | 22 | 6 (3.3%) | Jilin, Liaoning, Hebei, Inner Mongolia, Gansu, Qinghai, Shaanxi, Ningxia, Shanxi, Shandong, Jiangsu, Zhejiang, Henan, Sichuan, Anhui, Hubei, Guangxi, and Yunnan (67%). |
| 2002[e] | 16 | 13 | 3.9 | 7 | 0.9 (0.5%) | Heilongjiang, Jilin, Liaoning, Hebei, Inner Mongolia, Gansu, Shanxi, Shandong, Jiangsu, Henan, Shaanxi, Sichuan, Qinghai, Tibet, Fujian, and Guangdong (59%). |
| 2003[f] | 27 | 15 | 4.5 | 17 | 4.5 (2.2%) | Jilin, Hebei, Gansu, Shanxi, Shandong, Henan, Shaanxi, Sichuan, Anhui, Zhejiang, Fujian, Jiangxi, Hunan, Guizhou, Yunnan, Guangxi, and Guangdong (63%). |
| 2004[g] | 23 | 16 | 2.5 | 4 | 3.2 (1.3%) | Heilongjiang, Jilin, Liaoning, Inner Mongolia, Sichuan, Anhui, Zhejiang, Fujian, Jiangxi, Hunan, Yunnan, Guangxi, Guangdong, and Hainan (52%). |
| 2005[h] | 9 | 15 | n.a.[i] | 9 | n.a. | Gansu, Qinghai, Shanxi, Sichuan, Guizhou, Yunnan, Guangxi, Guangdong, and Hainan (33%). |

Sources:
[a]FAO (1997) and NBS (2005). [b]The Boston Globe (1999/03/31). [c]AP (2000/06/28), China Daily (2000/06/04), FAO (2000), ReliefWeb (2000/06/15). [d]China Daily (2001/05/06, 2001/05/28, 2001/06/07), FAO (2001), People's Daily (2001/10/31, 2001/11/06, 2001/11/30), and Xinhua News Agency (2001/05/29, 2001/06/28). [e]China Daily (2002/03/05, 2002/05/09), People's Daily (2002/08/14), and Xinhua News Agency (2002//03/18, 2002/05/04). [f]China Daily (2003/03/27, 2003/08/01, 2003/08/05, 2003/08/06, 2003/08/14), Xinhua News Agency (2003/03/12, 2003/08/04). [g]China Daily (2004/03/31, 2004/07/24, 2004/07/26, 2004/07/30, 2004/08/12, 2004/08/23, 2004/11/04, 2004/11/22, 2004/12/02, 2004/12/22), MWR (2004), and Xinhua News Agency (2004/08/14, 2004/11/11, 2004/11/12, 2004/12/23). [h]AFP (2005/12/29), China Daily (2005/04/04, 2005/04/11, 2005/08/12), and Xinhua News Agency (2005/02/26, 2005/10/11). Others: NBS (2005). [i]n.a. means information not available. [j]Numbers in parentheses are the percentage of agricultural sector GDP. [k]Numbers in parentheses indicate the proportion of administrative area of the country affected.

3. To analyze the economic consequences of drought at the farm-household level and farmers' drought-coping mechanisms,
4. To investigate institutional understanding of drought in rice and its management strategies, and
5. To suggest alternative options for technology and policy interventions for the effective management of drought risk.

This chapter is organized into six sections. It begins with a general discussion of the drought problem in the major rice production systems of southern China. Section 2 presents a short description of the analytical methods used for characterizing drought, estimating the aggregate- and household-level impact of drought, and examining farmers' drought-coping mechanisms. The empirical findings of the study are described in subsequent sections. Section 3 presents the rainfall characteristics, probability of drought, and estimation of production losses at the aggregate level. Section 4 discusses household characteristics and production systems in a normal year, the household-level impacts of drought, and farmers' drought-coping mechanisms. A critical overview of policies and institutional setup for drought management in southern China is provided in Section 5. The final section concludes with a discussion of the overall implications for technology design and for policy improvements for long-term drought mitigation and drought relief.

## 2. Research design and data generation

This study focuses on southern China.[2] In terms of rice ecological zoning, southern China accounts for 88% of the total rice area and 86% of the total rice production of the country (Zhu 2000). Southern China is divided into three regions: southwestern, south-central, and southeastern. The level of development increases from west to east in southern China. One province is selected from each of these three regions for this study: Guangxi in the southwestern,[3] Hubei in the south-central, and Zhejiang in the southeastern region. These three provinces represent the major rice-growing areas of each region. The major features of these three provinces are summarized in Table 6.2. Overall, Guangxi represents a poorer area, with a low proportion of irrigation and low rice yields.

Two types of analysis are conducted to meet the objectives of the study. The first involves the analysis of published temporal data on rainfall and crop production. The selected three provinces in southern China are included for secondary analysis. Published temporal data on rice production and monthly rainfall for 10 geographically

[2]In terms of administrative and economic features, southern China is further divided into the southeastern coastal region, south-central region, and southwestern region. The southeastern coastal region includes five provinces (Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan), the south-central region includes five provinces (Henan, Anhui, Hubei, Jiangxi, and Hunan), and the southwestern region includes three provinces (Guizhou, Yunnan, and Sichuan), one minority autonomous region of Guangxi, and one municipality of Chongqing..

[3]Guangxi is an autonomous region—the Guangxi Zhuang Autonomous Region. It is equivalent to a province at the administrative level.

**Table 6.2. Basic socioeconomic indicators of the study provinces, China, 2003.**

| Item | Guangxi | Hubei | Zhejiang | China |
|---|---|---|---|---|
| Location | Southwest | South-central | Southeast | – |
| Population (million persons) | 49 | 60 | 47 | 1,292 |
| Agricultural sector GDP (% of total GDP) | 24 | 15 | 8 | 15 |
| Rural per capita income (US$)[a] | 262 | 321 | 673 | 328 |
| Annual average rainfall (mm) | 1,510 | 1,150 | 1,520 | 1,000–2,000 |
| Irrigated area (% of cultivated area) | 34 | 41 | 66 | 42 |
| Rice area (million ha)[b] | 2.4 | 1.9 | 1.0 | 27.0 |
| Rice yield (t $ha^{-1}$)[b] | 5.1 | 7.4 | 6.6 | 6.1 |

[a]Exchange rate used: US$1 = yuan 8.0. [b]Rice area and yield values are estimated based on 2001-03 triennium average.
Source: NBS (2005).

representative counties[4] in each of the three provinces covering the period 1982-2001 are used for characterizing drought and for estimating the impact of drought at the aggregate level. Rice production characteristics for the province as a whole are analyzed using province-level data. Recorded rainfall data from different weather stations at the county level in each province are used to compute the mean monthly rainfall for each province. The average of rainfall recorded in all stations of 10 counties in a province is used to represent rainfall for the province.

Drought is defined in terms of a deficiency of actual rainfall compared to the long-term average (LTA) rainfall of the study provinces. Following a similar approach used in India (Pandey et al 2000), drought is considered to have occurred in a particular year if rainfall during the monsoon season (June-November)[5] is less than 80% of the LTA. The rice-growing season is divided into three periods—the spring season (March-May), the summer season (June-August), and the autumn season (September-November)—for assessing the incidence of drought during different periods and its impact on rice production. The frequency of drought during each period is estimated as the number of years in which rainfall is below 80% of the LTA for that particular period.

The basic analytical approach followed is described in Chapter 3. Two specifications are used to estimate the aggregate impact of drought on rice production. The first involves the estimation of a continuous relationship between production and rainfall using historical data. Production is expected to suffer when rainfall is too little or

[4]Counties in Guangxi are Bobai, Fuchuan, Guiping, Liucheng, Longzhou, Nandan, Shangsi, Tengxian, Tianlin, and Xingan; counties in Hubei are Enshi, Fangxian, Gongan, Lichuan, Luotian, Suizhou, Xiangyang, Yangxin, Yichang, and Yunxian; counties in Zhejiang are Cangnan, Changshan, Changxing, Cixi, Fuyang, Jiashan, Linhai, Qingyuan, Shangyu, and Yiwu.
[5]This is a summer-autumn season in China that covers the critical growing period of both the single- and double-rice systems.

too much. This effect can be captured by specifying production (Q) as a quadratic function of rainfall:

$$Q = a + bT + cR + dR^2 + u \qquad (1)$$

where R is rainfall, T is a trend variable capturing the effect of technological changes, and $u$ refers to the random error term with the usual regression properties. In the specification above, the coefficients $c$ and $d$ measure the response to rainfall. It is anticipated that $c>0$ and $d<0$. This equation can be used to estimate the elasticity of production with respect to rainfall.

In the second specification for estimating the production loss due to drought, a discrete drought dummy variable is specified in a linear trend equation. The model is specified as

$$Q = a + bT + cD + u \qquad (2)$$

As previously defined, T refers to the time trend, which captures the effect of technological change, and D is the drought dummy. The drought dummy variable takes the value of 1 in drought years and zero otherwise. The coefficient $c$ measures the average effect of drought on production when all drought years are considered.

The production loss estimated above (i.e., based on rainfall or drought dummy) measures the average loss for drought years *only*. This needs to be weighted by the probability of drought to estimate the average loss *per year* over a run of years. The probabilities of drought estimated from the analysis of rainfall data are used for this purpose.

The second type of analysis involves the investigation of the household-level effects of drought and farmers' coping mechanisms using farm household survey data. For this, one county is selected from each of the three provinces. The selected counties are Nandan, Xiangyang,[6] and Qingyuan in Guangxi, Hubei, and Zhejiang provinces, respectively (Fig. 6.2). Households were selected from these counties using a random sampling approach from villages identified to be representative of drought-prone environments. A total of 153 households from five villages in three counties were selected for the farm-level analysis (Table 6.3). Rice is an important crop in all these counties and they represent both rainfed and irrigated production systems (Table 6.4).

In addition to formal surveys, participatory rural appraisals, key informants' surveys, focus group discussions, and case studies were conducted to collect qualitative information to complement the quantitative data. Information on public-sector programs for drought management was collected from various government institutions and was used to assess the nature of policy responses. Agricultural officials, agricultural technicians, and scientists in relevant government departments and research institutes working on drought at the province, county, and township level were interviewed

[6]Xiangyang County was renamed administratively as Xiangyang District under Xiangfan City at the time of the fieldwork of this project.

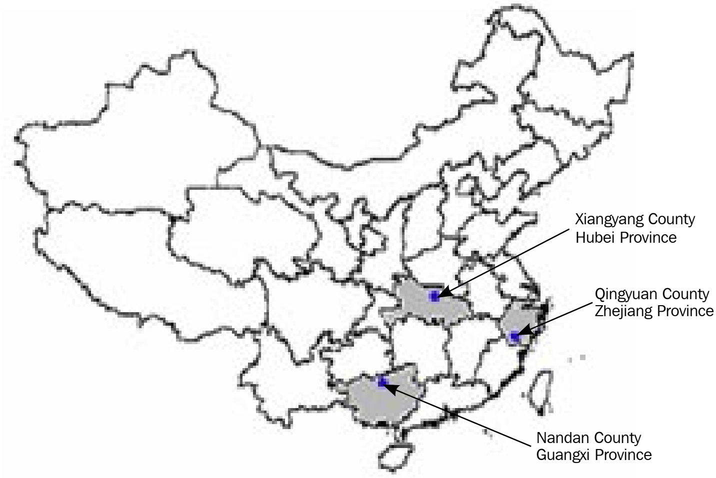



**Fig. 6.2. Map of China showing study counties and provinces.**

**Table 6.3. Name of the study provinces, counties, and villages, China.**

| Province | District | County | Township | Village | Number of sample households |
|---|---|---|---|---|---|
| Guangxi | Hechi | Nandan | Yueli | Yueli | 30 |
| | | | Baxu | Baxu | 30 |
| Hubei | Xiangfan | Xiangyang | Dongjin | Heli | 31 |
| | | | Huopai | Huopai | 31 |
| Zhejiang | Lishui | Qingyuan | Hedi | Hedi | 31 |

**Table 6.4. Socioeconomic and rice production indicators, selected counties, 2001.**

| Variable | County | | |
|---|---|---|---|
| | Nandan (Guangxi) | Xiangyang (Hubei) | Qingyuan (Zhejiang) |
| Population (000 persons) | 283 | 1,003 | 197 |
| Crop sown area (000 ha) | 36 | 174 | 16 |
| Rice area (000 ha) | 8.7 | 73.1 | 9.0 |
| Rice production (000 t) | 58 | 549 | 53 |
| Rice yield (t $ha^{-1}$) | 6.7 | 7.5 | 5.9 |
| Irrigated area (% of crop sown area) | 15 | 48 | 58 |
| Farmers' per capita income (US$) | 230 | 370 | 280 |
| Annual average rainfall during 1982-2001 (mm) | 1,540 | 820 | 1,760 |

Data source: Guangxi Statistical Yearbook (2002), Hubei Statistical Yearbook (2002), Zhejiang Statistical Yearbook (2002).

**Table 6.5. Selection of normal and drought years.**

| Item | Yueli (Nandan, Guangxi) | Baxu (Nandan, Guangxi) | Heli (Xiangyang, Hubei) | Huopai (Xiangyang, Hubei) | Hedi (Qingyuan, Zhejiang) |
|---|---|---|---|---|---|
| Normal year | 2001 | 2001 | 2001 | 2001 | 2001 |
| Drought year | 1999 | 1996 | 2000 | 2000 | –[a] |

[a]The drought year was not reported.

for this purpose. Information regarding their understanding of the nature and impact of drought on rice as well as available technological and institutional strategies for drought mitigation were elicited using pretested semistructured questionnaires. The survey of farm households and government institutions was carried out in different periods in 2002. Farm household-level impacts of drought were derived by comparing production practices in "normal" years with those in "drought" years. Representative "normal" and "drought" years identified by farmers for each village are presented in Table 6.5.

## 3. Aggregate-level analysis

This section describes the trends in rice production, characteristics of rainfall, and frequency of drought occurrence in southern China. In addition, rainfall elasticity of rice production as well as rice production losses due to drought at the aggregate level are discussed using time-series data from 1980 to 2001. The results and discussion in this section are based on an aggregate (i.e., province)-level analysis.

### 3.1 Trends in rice production in selected provinces in southern China

Rice yield and production have steadily increased over time despite some contraction in rice area in recent years. The national average yield of 2.1 t $ha^{-1}$ in 1950 reached 6.1 t $ha^{-1}$ in 2003, with the annual growth rate being 2.3%. Production grew at 2.5% per annum during this period (Fig. 6.3).

Rice production systems in China can be classified into double-rice and single-rice systems. The double-rice system has two crops of rice per year, the early season (February-June) and the late season (June-November). The single-rice system has only one crop of rice (April-October) per year. The area share of the double-rice system and single-rice system is 45% and 55%, respectively (Table 6.6). Based on 2001-03 data, the average yield of the single-rice system is higher (6.8 t $ha^{-1}$) than that of either crop in the double-rice system.

The three selected provinces (Guangxi, Hubei, and Zhejiang) in southern China account for 20% of both the total rice area and total rice production of the country.

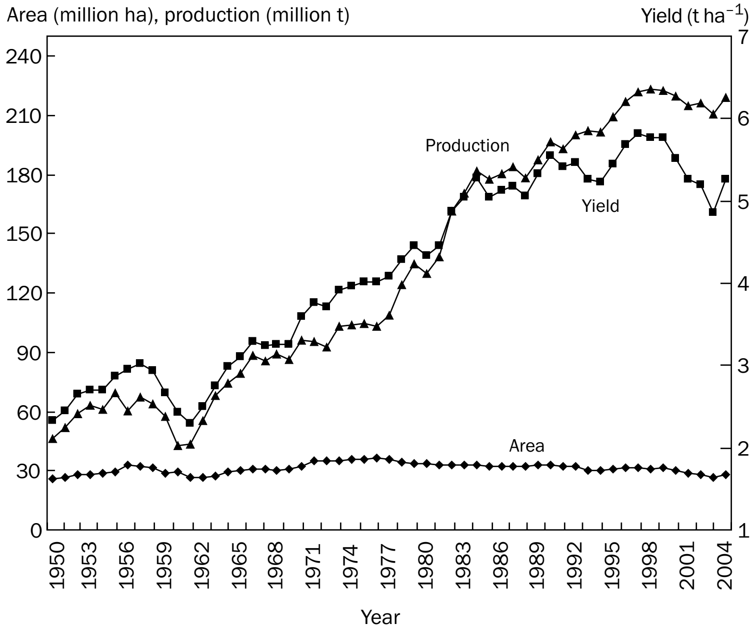



**Fig. 6.3. Trends in rice area, yield, and production, China, 1950-2004.**

During 2001-03, the average rice yield in Guangxi, Hubei, and Zhejiang was 5.1, 7.4, and 6.6 t $ha^{-1}$, respectively.

Over the last five decades, rice area increased initially, but started to decrease after the mid-1980s (Fig. 6.4A to 6.4C). During 1970-2003, the annual growth rate of production in Guangxi, Hubei, and Zhejiang was 1.7%, 1.5%, and 0%, whereas the yield growth rate for these provinces was 2.4%, 2.7%, and 1.7%, respectively. The growth rate in rice area was negative in all three provinces (Table 6.7).

## 3.2 Rainfall and drought characteristics

The rainfall and drought characteristics in three selected provinces in southern China were estimated using county-level data covering 1982-2001. The average annual rainfall in southern China is 1,391 mm. The monsoon rains start in May, peak during June and July, and taper off in September (Fig. 6.5). The distribution of annual rainfall is 29% in the spring season (March to May), 42% in the summer season (June to August), 18% in the autumn season (September to November), and 11% in the winter season (December to February), as shown in Table 6.8. The summer-autumn season (June-November), hereafter referred to as the monsoon period, covers the main rice-growing season and accounts for about 60% of the annual rainfall. Rainfall is characterized by high spatial variability (Fig. 6.6A to 6.6C).

The probability estimates of drought, using the meteorological definition of drought as discussed in Section 2, are presented in Table 6.9. The monsoon drought

**Table 6.6. Triennium average rice area and yield by season, China, 2001-03.**

| Province | Type of rice | Area (000 ha) | Area (% of total) | Yield (t ha$^{-1}$) |
|---|---|---|---|---|
| Guangxi | All | 2,397 | | 5.1 |
| | Early-season | 1,130 | 47 | 5.3 |
| | Late-season | 1,133 | 47 | 4.8 |
| | Single-season | 134 | 6 | 5.7 |
| Hubei | All | 1,908 | | 7.4 |
| | Early-season | 326 | 17 | 5.4 |
| | Late-season | 420 | 22 | 6.1 |
| | Single-season | 1,162 | 61 | 8.5 |
| Zhejiang | All | 1,164 | | 6.6 |
| | Early-season | 215 | 19 | 5.4 |
| | Late-season | 283 | 24 | 6.2 |
| | Single-season | 666 | 57 | 7.2 |
| China | All | 27,840 | | 6.1 |
| | Early-season | 5,950 | 21 | 5.3 |
| | Late-season | 6,552 | 24 | 5.4 |
| | Single-season | 15,338 | 55 | 6.8 |

Data source: China government crop plantation information (online data accessed in August 2005). Online at http://zzys.agri.gov.cn.

probability is 15% in Guangxi, 10% in Hubei, and 15% in Zhejiang. Thus, drought during the major rice-growing season is less frequent in Hubei than in the other two provinces. In terms of the seasonal distribution, summer and autumn droughts are more frequent than spring drought. Overall, the probability of drought in different seasons varies from 10% to 30% across the provinces.

The probability of spatially covariate drought[7] was estimated using the county-level rainfall data (Table 6.10). The overall probability of covariate drought in southern China was estimated to be 10% during each of the spring and summer seasons, 30% during the autumn season, and 11% during the monsoon season. Thus, autumn drought is relatively more covariate spatially than spring and summer droughts. At the provincial level, the probability of covariate drought during spring, summer, autumn, and monsoon is 12–50%, 13–36%, 33–43%, and 13–36%, respectively. Overall, drought events in southern China are not highly covariate.

## 3.3 Aggregate impact of drought

The observed temporal fluctuations in yield and area are the results of many stochastic factors, including drought. The size of the temporal fluctuations can, hence, provide

[7]The covariate drought refers to drought that covered more than 50% of the counties surveyed in a province.

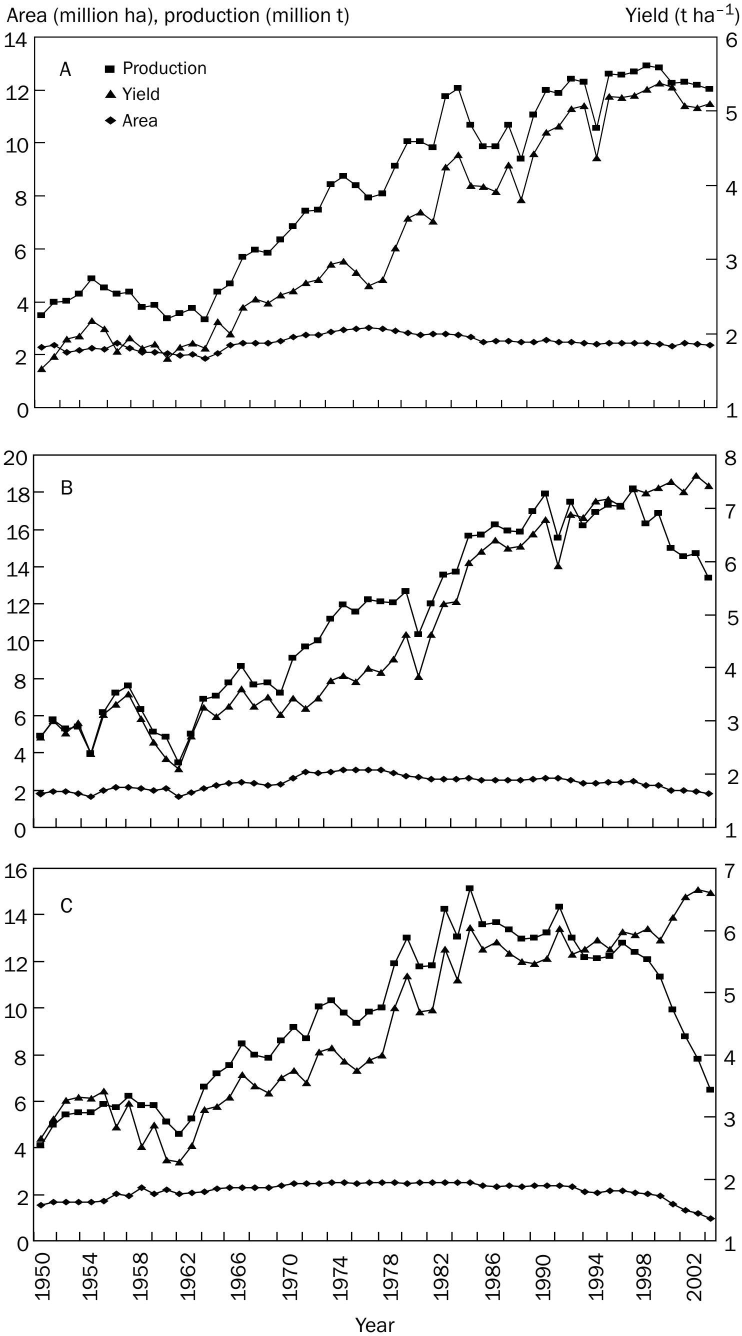



**Fig. 6.4. Trends in rice area, yield, and production, 1950-2003. (A) Guangxi, (B) Hubei, (C) Zhejiang.**

**Table 6.7. Compound annual growth rate (%) of rice area, yield, and production, China, 1970-2003.**

| Province | Area[a] | Yield | Production |
|---|---|---|---|
| Guangxi | –0.71* | 2.35* | 1.65* |
| Hubei | –1.21* | 2.74* | 1.53* |
| Zhejiang | –1.70* | 1.68* | –0.01 |
| China | –0.62* | 2.25* | 1.64* |

[a]* means statistically significant values at the 5% probability level.

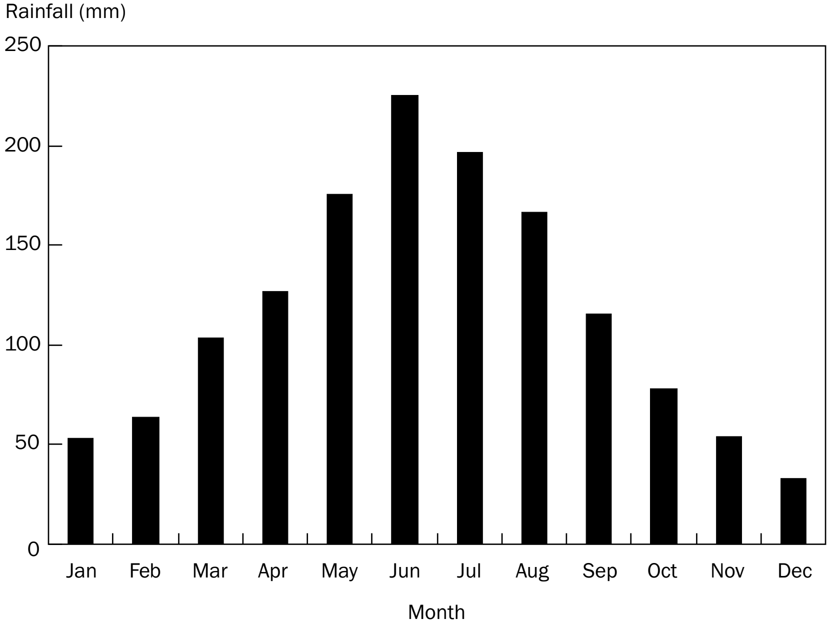



**Fig. 6.5. Monthly long-term average rainfall in southern China, 1982-2001.**

**Table 6.8. Long-term average rainfall in different seasons, southern China, 1982-2001.**[a]

| Province | Percent of annual rainfall (%) | | | | | Annual average rainfall (mm) |
|---|---|---|---|---|---|---|
| | Spring | Summer | Autumn | Winter | Monsoon | |
| Guangxi | 30 | 44 | 16 | 10 | 60 | 1,511 |
| Hubei | 26 | 45 | 21 | 8 | 66 | 1,146 |
| Zhejiang | 30 | 39 | 18 | 13 | 57 | 1,516 |
| Southern China | 29 | 42 | 18 | 11 | 60 | 1,391 |

[a]The seasonal drought for China is defined based on the following time periods: spring: March-May, summer: June-August, autumn: September-November, winter: December-February, and monsoon: June-November.

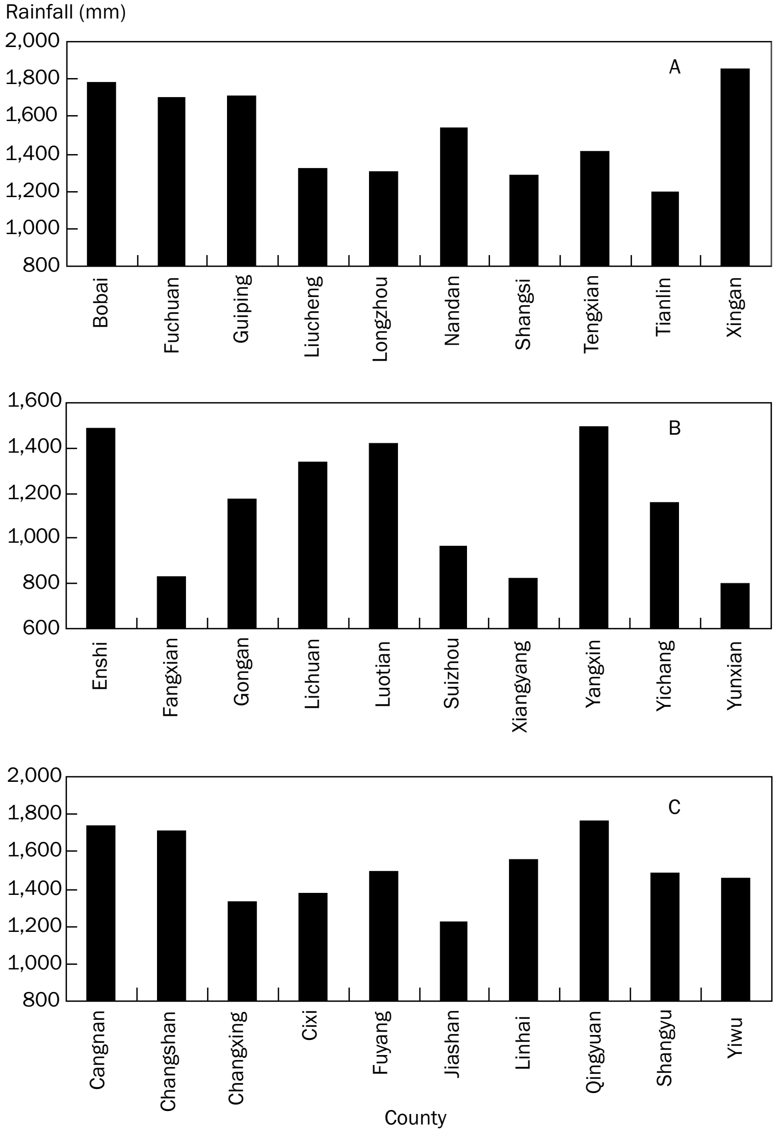



**Fig. 6.6. Annual long-term average rainfall, by county, 1982-2001, for (A) Guangxi, (B) Hubei, and (C) Zhejiang provinces.**

**Table 6.9. Probability of drought, southern China, 1982-2001.**[a]

| Province | Spring | Summer | Autumn | Monsoon |
|---|---|---|---|---|
| Guangxi | 0.15 | 0.30 | 0.25 | 0.15 |
| Hubei | 0.15 | 0.20 | 0.20 | 0.10 |
| Zhejiang | 0.25 | 0.15 | 0.30 | 0.15 |

[a]Drought is considered to have occurred when monsoon (June-November) rainfall is less than 80% of the long-term average.

**Table 6.10. Probability of covariate drought,**[a] **southern China, 1982-2001.**

| Province | Spring | Summer | Autumn | Monsoon |
|---|---|---|---|---|
| Guangxi | 0.12 | 0.36 | 0.43 | 0.36 |
| Hubei | 0.13 | 0.13 | 0.33 | 0.13 |
| Zhejiang | 0.50 | 0.22 | 0.38 | 0.21 |
| Southern China | 0.10 | 0.10 | 0.30 | 0.11 |

[a]Covariate drought years refer to those drought years that occurred in over 50% of the counties of the province.

**Table 6.11. Estimated coefficient of variation (%) of rice area, yield, and production, southern China, 1970-2003.**[a]

| Province | Area | Yield | Production |
|---|---|---|---|
| Guangxi | 4 | 7 | 7 |
| Hubei | 5 | 6 | 8 |
| Zhejiang | 6 | 6 | 8 |

[a]Coefficients of variation were estimated using quadratic de-trended data.

some indications of the likely overall magnitude of the effect of drought. Here, coefficients of variations estimated using quadratic de-trended time-series data on rice area, yield, and production are used for an initial analysis.

Overall, the province-level area, yield, and production variability as measured by the coefficients of variation (CV) in the three provinces of southern China are low and are in the range of 4–6%, 6–7%, and 7–8%, respectively (Table 6.11). Temporal variations in area are high among counties in Hubei and Zhejiang, while yield variations are high among counties in Guangxi.

**Table 6.12. Rainfall elasticity estimates of rice area, yield, and production, southern China, 1982-2001.[a]**

| Province | Area | Yield | Production |
|---|---|---|---|
| Guangxi | 0.09* | –0.04 | 0.05 |
| Hubei | 0.07 | –0.04 | 0.03 |
| Zhejiang | 0.05 | –0.12* | –0.07 |

[a]Rainfall from April-May is used to evaluate the effect of rainfall on rice area, while rainfall from June-November is used to evaluate the effect of rainfall on rice yield and production.
*indicates statistically significant values at the 5% probability level.

The analysis of time-series data on rainfall and yield can give some indications of the correlation between the drought events as defined and yield. The small correlation coefficient between rice yield and monsoon rainfall, which ranges from 0.05 to 0.23 across three selected provinces, indicates a poor relationship between these two variables for southern China. This weak correlation may be due to irrigation, which accounts for 34–66% of cultivated area in the provinces studied (Table 6.2). As a result, the impact of drought on rice yield and production in the area analyzed is unlikely to be substantial at the aggregate level.

To investigate the impact of drought further, elasticity of rice area, yield, and production is estimated using the methodology described in Section 2 (see Chapter 3 for details). The analysis is conducted using data for the period 1982-2001 for 10 counties in each province for which the required rainfall and production data were available.[8] Very few elasticity coefficients are, however, found to be statistically significant. At the provincial level, the estimated area elasticity is significant only for Guangxi but not for Hubei and Zhejiang (Table 6.12). The estimated rainfall elasticity of rice area of 0.09 for Guangxi implies that a 10% reduction in rainfall from the LTA will reduce the rice area by about 1% in this province. Since drought here is defined as at least a 20% drop in rainfall, the corresponding reduction in rice area would be 2%. The estimated yield elasticity is significant only in Zhejiang but not in Guangxi and Hubei. Overall, the effect of rainfall variation in rice production does not seem significant, even though rice area planted and/or yield may be affected in some cases.

The effect of drought on rice production is also examined using the drought dummy variables as described in Section 2 (see Chapter 3 for details). The ordinary least square estimates of the effect of monsoon-season drought on rice production using the dummy variable model are presented in Table 6.13. The coefficient of the drought dummy variable provides a measure of the average production losses during drought years. For example, the marginal coefficient of the drought dummy in Hubei implies that the average rice production loss in Hubei in drought years is 680,000

[8]In southern China, rice is planted mainly during April and May. Hence, April-May rainfall is used to examine the effect of rainfall on rice area. On the other hand, the monsoon-period (June-November) rainfall is used to evaluate the effect of rainfall on rice production and yield.

**Table 6.13. Ordinary least square estimates of effect of monsoon season drought dummy on rice production, southern China, 1982-2001.**[a]

| Province | Mean output (000 t) | Drought year production losses: Quantity[b] (000 t) | Value (million US$) | Percent (%) | Monsoon drought probability (*P*) | Annual production losses[c] (%) |
|---|---|---|---|---|---|---|
| Guangxi | 11,636 | 32 ns[d] | 3.68 | 0.3 | 0.15 | 0.04 |
| Hubei | 16,154 | 676 ns | 77.74 | 4.2 | 0.10 | 0.42 |
| Zhejiang | 12,660 | 447 ns | 51.41 | 3.5 | 0.15 | 0.53 |

[a]Dependent variable: production (000 t). Rice price of US$115 $t^{-1}$ is used to compute the value of production losses. Estimates of production losses are based on monsoon drought dummy model. Drought dummy is defined as years with monsoon-period (June-November) rainfall less than 20% of the long-term average. [b]Values are the coefficients of drought dummy. [c]Percent refers to the proportion of sample mean production during 1982-2001. [d]ns means statistically nonsignificant values.

tons. The estimated loss ranges between 0.3% and 4.2% of the average output. These loss estimates are not, however, statistically significant in any of the three provinces, implying that drought does not result in any statistically significant production losses at the provincial level. This result is in conformity with the estimates of elasticity discussed earlier.

The effect of drought on other crops (maize and wheat) was also investigated using the dummy variable model. However, none of the effects are statistically significant, hence the finding for rice also generally applies to these other major crops.

The province-level analysis shows that drought results in rice production losses of up to 4.2% in southern China, although the value is not statistically significant. The statistical insignificance is probably due to confounding effects of low and high rainfall as well as relatively good and poor rice production environments over such large areas. Using a slightly lower level of spatially aggregated data (i.e., a prefecture level) and a different methodology, the average rice yield loss due to drought estimated in other studies is about 3–5% (Dey and Upadhyaya 1996, Lin and Shen 1996).

## 4. Farm-level analysis

The major characteristics of rice production systems, household income structure, and farm-level impacts of drought are discussed in this section. The drought impacts are analyzed by comparing farming practices, crop yields, and net returns between "normal" and "drought" years. The results and discussions are based on farm household survey data.

**Table 6.14. General characteristics of sample households, southern China.**

| Household characteristics | Guangxi | Hubei | Zhejiang | Overall |
|---|---|---|---|---|
| Average household size (no.) | 4.7 | 4.3 | 4.9 | 4.6 |
| Average age of household head (years) | 45 | 47 | 49 | 47 |
| Average years in school of HH head (years) | 6.0 | 6.7 | 6.3 | 6.3 |
| Literacy rate (% of sample population)[a] | 82 | 69 | 85 | 77 |

[a]Literacy rate is computed based on the economically active population (16–64 years of age).

**Table 6.15. Landholding characteristics of sample households, southern China.**

| Landholding characteristics | Guangxi | Hubei | Zhejiang | Overall |
|---|---|---|---|---|
| Sample size (no. of households) | 60 | 62 | 31 | 153 |
| Average farm size (ha household$^{-1}$) | 0.42 | 0.77 | 0.38 | 0.55 |
| Average number of parcels (no. household$^{-1}$) | 15 | 5 | 7 | 9 |
| Rice land (ha household$^{-1}$) | 0.27 | 0.54 | 0.33 | 0.39 |
| Nonrice land (ha household$^{-1}$) | 0.15 | 0.23 | 0.05 | 0.16 |

## 4.1 Major characteristics of the rice production systems and household economy

General characteristics of the sample households and their demographic features are presented in Table 6.14. Overall, the average household size is 4.6, with the household head having an average schooling of 6 years. The literacy level is high at 77%.

Farmers classify farmland into "rice land" and "nonrice land." Rice land is normally located near irrigation sources. Nonrice lands are mostly unirrigated, although some rice may be grown even in these rainfed areas. These two types of land, however, may be switched over as the water availability may change from time to time. A typical rice farmer normally has both types of land. Irrigated land may be further classified as land with "good irrigation" and land with "poor irrigation." Land with good irrigation has an assured supply of irrigation, whereas the water supply is not assured in land with poor irrigation, even though irrigation facilities may exist.

The average farm size (land area) per household is 0.42 ha, 0.77 ha, and 0.38 ha for Guangxi, Hubei, and Zhejiang, respectively, with an overall average of 0.55 ha, of which 71% is rice land (Table 6.15). The proportion of rice land is highest in Zhejiang (87%) and the lowest in Guangxi (66%). The study area in Guangxi is mostly mountainous, with rough and rocky terrain, and hence has a smaller proportion of rice land. Zhejiang and Hubei have a higher proportion of land with good irrigation than Guangxi, which has mostly rainfed land and land with poor irrigation. The average number of parcels per household is 9. The extent of land fragmentation in Guangxi is much higher than in the other two provinces.

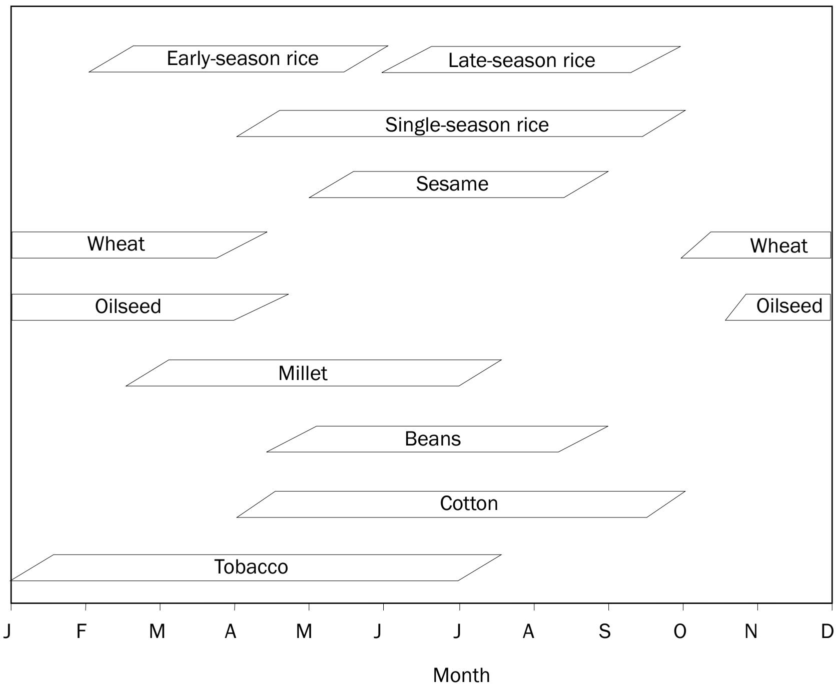



**Fig. 6.7. Cropping calendar (planting to harvesting) in study areas, southern China.**

Rice, maize, beans, and cotton are the major crops grown in summer (May-October), and wheat, oilseeds, and vegetables are the major crops in winter (November-April). Cropping patterns (or crop sequences grown in a year) vary only slightly across the study provinces (Fig. 6.7). Rice-wheat and rice-oilseeds represent the two major cropping systems on rice land. On nonrice land, the major cropping systems are cotton-wheat and maize-wheat. Nonrice land in Guangxi villages is mostly fallowed in winter. In Zhejiang, both rice and nonrice lands are left fallowed in winter (Table 6.16).

Labor, chemical fertilizers, seeds, and plant protection are the major inputs used in rice production. Overall, the average cost of rice production is \$580 $ha^{-1}$, but it varies from \$470 to \$630 $ha^{-1}$ (Table 6.17). The cost of production is highest in Zhejiang, which is located in the southeast region and is more economically developed, mainly because of high opportunity costs of labor. Labor is the main input in rice production, accounting for 70% of the total cost. The cost of chemical fertilizer is the highest among all material inputs and accounts for 21% of the total cost. The costs of machinery and herbicide are insignificant.

**Table 6.16. Cropping pattern of the study areas in a normal year, southern China.**

| Land type | Season | Guangxi | Hubei | Zhejiang |
|---|---|---|---|---|
| Irrigated land (rice land) | Summer | Rice | Rice | Rice |
| | Winter | Wheat/vegetable | Wheat/oilseed | Fallow |
| Rainfed land (nonrice land) | Summer | Maize/sesame | Cotton/bean | Sweet potato |
| | Winter | Fallow | Wheat | Fallow |

**Table 6.17. Costs and returns (US\$ ha$^{-1}$) of rice production among sample households, southern China.**

| Item | Guangxi | Hubei | Zhejiang | Overall |
|---|---|---|---|---|
| Total input cost (US\$ ha$^{-1}$) | 470 | 500 | 630 | 580 |
| Input cost share (% of total costs) | | | | |
| Labor[a] | 63 | 67 | 74 | 70 |
| Machines | 1 | 1 | 1 | 1 |
| Seeds | 7 | 4 | 3 | 4 |
| Chemical fertilizer | 24 | 22 | 19 | 21 |
| Herbicide | 1 | 1 | 0 | 0 |
| Pesticide | 4 | 5 | 3 | 4 |
| Gross returns (US\$ ha$^{-1}$)[b] | 550 | 900 | 530 | 700 |
| Net returns (US\$ ha$^{-1}$)[c] | 80 | 400 | –100 | 120 |

[a]Labor costs include both family and hired labor used for rice production. [b]Gross returns are estimated as per hectare yield of rice multiplied by farm-gate price of rice. [c]Net returns are estimated as gross returns minus total input costs.
Exchange rate used: US\$1 = yuan 8.0.

The average gross return from rice production is \$700 ha$^{-1}$, ranging from \$530 to \$900 ha$^{-1}$. The significantly higher gross return in Hubei is mainly due to higher rice yield in the province. The average net return (i.e., gross return minus input costs) is about \$120 ha$^{-1}$. Of the three provinces, the net return is highest in Hubei but turns out to be negative in Zhejiang because of the high opportunity cost of family labor. The difference in returns across provinces is mainly driven by the yield and labor cost differences.

Household income and its composition during normal years are presented in Table 6.18. The overall average household income is \$860. Income from farm activities including crop cultivation and animal husbandry accounts for 54% of the total income. The average household income is highest in Hubei and lowest in Guangxi.

The high share of nonfarm income in the total income in Zhejiang indicates a much greater importance of nonfarm activities in this province than in the other two provinces. This is a more economically developed area with more opportunities for

**Table 6.18. Income[a] per household during a normal year in study areas, by sources, southern China.**

| Item | Guangxi | Hubei | Zhejiang | Total |
|---|---|---|---|---|
| Total income (US$ $hh^{-1}$) | 650 | 1,010 | 960 | 860 |
| Income share (% of total income) | | | | |
| Farm income[b] | | | | |
| All crops | 28 | 56 | 20 | 39 |
| Rice | 15 | 30 | 13 | 22 |
| Animal husbandry | 25 | 10 | 12 | 15 |
| Nonfarm[c] | 47 | 34 | 68 | 46 |

[a]Total income includes farm and nonfarm income. Farm income is derived from crops and animal husbandry (mostly pig rearing), while nonfarm income comes mainly from family-based agricultural product processing, local trading, handicrafts, local labor work, and migrant labor work. Rice production is one of the main crop cultivation activities in the study area and its income is investigated separately. [b]Farm income is separated into the following items: (1) Crop income, which is the summation of income from each crop cultivated, which is the value of crops produced net of input costs, including seeds, fertilizers, and pesticides. The cost of family labor input is not included in this calculation. (2) Income from animal husbandry is the summation of the value of livestock sold net of input costs. [c]Nonfarm income is the summation of income from each of the nonfarm activities.

**Table 6.19. Decomposition of household average income (% share), by income quartiles, southern China.**

| Source of income | Household income quartile | | | |
|---|---|---|---|---|
| | Bottom quartile | 25–50% | 50–75% | Top quartile |
| Rice | 42 | 29 | 25 | 19 |
| Nonrice | 17 | 19 | 23 | 18 |
| Livestock | 30 | 24 | 21 | 13 |
| Nonfarm | 11 | 28 | 31 | 50 |

nonfarm employment. In the other two provinces that are less economically developed, the share of nonfarm income is lower. The overall average share of rice income in total income is 22%, with a range of 13–30%.

When examined by income quartiles, the share of rice in total household income is highest (42%) for the bottom quartile (Table 6.19). This means that the lower-income farmers derive a larger share of their income from rice, and are thus more dependent on rice production for their livelihoods than the top-quartile group, which derives only 19% of the total income from rice. Any loss in rice production is thus likely to have a greater impact on the low-income group.

## 4.2 Farm- and household-level impact of drought

Overall, rice occupies 44% of the total cultivated area in normal years but the share decreases to 33% during drought years (Table 6.20). The decrease in proportionate share of rice area to total sown area is highest in land with poor irrigation and is fol-

**Table 6.20. Changes in crop area, yield, and production (%) in drought year as compared with normal years, sample households, southern China.**

| Crop | Irrigation facilities | | | Province | | | Overall |
|---|---|---|---|---|---|---|---|
| | Good irrigation | Poor irrigation | Rainfed | Guangxi | Hubei | Zhejiang | |
| Area | | | | | | | |
| Rice | –10 | –32 | –3 | –1 | –37 | 1 | –19 |
| Wheat | 42 | 0 | 47 | –67 | 19 | 0 | 18 |
| Maize | –34 | 2 | –8 | 69 | –9 | –100 | –8 |
| Oilseed | >100 | >100 | 44 | 20 | 200 | 39 | 110 |
| Soybean | –100 | *[a] | –36 | –56 | 0 | * | –38 |
| Others | –13 | –43 | –23 | 8 | –36 | 7 | –28 |
| Yield | | | | | | | |
| Rice | –14 | –43 | –33 | –32 | –31 | –9 | –31 |
| Wheat | –31 | –11 | –38 | –58 | –22 | –60 | –22 |
| Maize | –48 | –27 | –46 | –88 | –30 | –100 | –36 |
| Oilseed | –85 | –84 | –30 | –29 | –78 | 31 | –62 |
| Soybean | –100 | * | –72 | –87 | –50 | * | –74 |
| Others | –65 | 28 | 56 | –44 | 43 | –6 | 27 |
| Production | | | | | | | |
| Rice | –23 | –61 | –35 | –32 | –57 | –9 | –44 |
| Wheat | –3 | –11 | –8 | –86 | –7 | –60 | –9 |
| Maize | –66 | –26 | –50 | –80 | –36 | –100 | –40 |
| Oilseed | –41 | –50 | 0 | –14 | –33 | 82 | –21 |
| Soybean | –100 | * | –82 | –94 | –50 | * | –84 |
| Others | –70 | –27 | 21 | –40 | –9 | 0 | –9 |

[a]* = an absolute value of less than 1.

lowed by land with good irrigation. The loss of rice area is proportionately the least in rainfed fields, but very little rice is grown under purely rainfed conditions.

The area of most nonrice crops in summer also decreased during drought years, although there is some expansion of area under oilseed, especially sesame. There was a compensating movement in the area of most winter crops as both wheat and oilseed area expanded during drought years. In Hubei, the expansion of area under wheat and oilseeds may be a strategy to compensate for the loss in rice production. In the other two provinces, there is very little change in the cropping pattern in nonrice land.

Thus, most of the adjustments in planting area of rice and cropping pattern are observed in Hubei but not in the other two provinces. Drought occurs mainly during the spring planting season in Hubei, affording farmers some flexibility for area adjustment. In the other two provinces, drought occurs later in the season—hence, area adjustment is relatively small.

Crop yields are lower in drought years for almost all crops and in all locations. For rice, the estimated yield losses are 9–32% depending on the location and 14-43% depending on irrigation facilities. The production losses of rice are 9–57% depending

**Table 6.21. Effect of loss in rice income on total income of households during a drought year, sample households, southern China.**

| Item | Household income quartile | | | | All |
|---|---|---|---|---|---|
| | Bottom quartile | 25–50% | 50–75% | Top quartile | |
| Share of rice income in total income (%) | 42 | 29 | 25 | 19 | 24 |
| Rice income loss during drought year (%) | 27 | 29 | 51 | 52 | 44 |
| Effect of drought on total income through loss in rice income (%) | 11 | 8 | 13 | 10 | 10 |

on location and 23–61% depending on irrigation facilities. The overall production losses of oilseeds are 14–50%. Production losses of wheat, cotton, maize, and beans are also substantial. These results indicate that the effect of drought at the farm level is substantial and spread across commodities and locations.

Although farm-level losses are substantial, production losses at the aggregate level appear to be relatively small. The lack of any evidence of drought-related losses at the aggregate level is not inconsistent, however, with the presence of large losses at the household level. Such a situation can arise if the drought effects are localized. Affected farmers in a village or a locality can suffer production losses. However, these localized effects may not be visible at the aggregate level because of the averaging out effect over a large area.

It is stated in the previous section that the share of rice income in total household income is higher among the poorer income groups. The proportionate loss in income due to a drop in rice production during drought years can be estimated by multiplying the share of rice income and the estimated proportionate drop in rice income during drought years. The results indicate that the proportionate loss in total income due to the drop in rice income during drought years is similar across income quartiles (Table 6.21). This share is approximately 10% across all income groups. Despite this, low-income groups are likely to suffer more due to their lower absolute income unless they are able to meet the income shortfall from some other sources.[9]

## 4.3 Rice farmers' coping strategies

Rice farmers who are exposed to drought risk practice various coping strategies. Over a long period of time, some of these strategies are incorporated into the nature of the farming system and are often not easily identifiable as risk-coping strategies. Others are employed only under certain risky situations and are easier to identify as responses to

[9]Bottom-quartile groups have a higher share of rice in total income, but their loss in rice income during drought years is proportionately lower. They seem to be able to protect their rice crop better than their higher-income counterparts. A detailed analysis indicated that the percentage loss in rice yield is similar across income categories, but the low-income groups are able to maintain the rice area while the higher-income groups reduced rice area substantially during drought years. The available data did not permit further analysis to explain this pattern.

risk. This section presents various drought-coping strategies used by farmers in three selected provinces in southern China based on farm household survey data.

Based on farm household survey data, shifts in cropping patterns and some adjustments in rice production practices seem to be the major tactical responses to drought (Table 6.20). As discussed in the previous section, some other crops such as sesame and soybeans are planted in place of rice when drought occurs during the rice planting season. Growing some other crops in place of rice is a loss-reducing and income-compensating strategy. Farmers also expand the area of the postrice crop if the rice crop is damaged by drought. However, the use of such an income-compensating strategy is not widespread in the study area. Only one-third of the farmers interviewed reported making such cropping pattern adjustments.

For rice, delaying transplanting during drought years is a major response. Rice is established by transplanting in the study area and, when rains are late and inadequate, farmers' only option is to delay transplanting. Obviously, the drop in rice yield due to delayed transplanting is the cost of this response. Where irrigation is available, farmers attempt to avoid this cost by pumping extra water, both during crop establishment and later growth periods. With two additional pumpings, the extra cost to rice farmers in Guangxi and Hubei is $90–200 per hectare, which raises the cost of production substantially (by 15–30%) during drought years. Rice farmers in Hubei may have to pay as much as $200 ha$^{-1}$ for pumping.[10] If this practice is adopted in one-third of the total rice area (i.e., 1.43 million ha) in Guangxi and Hubei, the total additional cost to farmers will be at least $130 million. Although part of this may be covered by the government through drought relief programs, this represents an overall additional cost to society.

Other tactical responses such as changing fertilizer quantity and timing and pest management practices, although reported by some farmers, are not widely practiced. Farmers seemed to follow the standard practice of rice production irrespective of the drought conditions (Table 6.22).

A majority of the farmers did not reduce expenditures on food consumption in response to drought. Households that reduced food consumption mentioned that they cut down on meat and other more expensive food items. Overall, farmers are able to absorb production losses through earning extra nonfarm income so that total income does not fall much during drought years.

There are two main reasons for a relatively limited impact of drought on total household income. The first is a well-diversified income structure. The importance of nonfarm (and nonrice) sources has increased over time as the Chinese economy continues to grow rapidly. The overall share of rice income in total household income is only about 22%. Farmers are able to cover any crop income deficit during drought years by seeking employment in the nonfarm sector. This provides a considerable protection against the welfare-reducing effect of drought.

[10]The cost of pumping paid by farmers can be separated into two parts: one is paid to a water-pumping station, which is managed at the township level, and the other is paid to village pumping facilities, which pump water from a canal to individual rice land.

**Table 6.22. Percentage of farmers reporting adjustment in crop management practices during a drought year, southern China.**

| Farmers' adjustment in crop management practices | Guangxi | Hubei | Zhejiang | Overall |
|---|---|---|---|---|
| Postponed transplanting date | 93 | 87 | 36 | 79 |
| Substitute rice with other crops | 26 | 64 | 7 | 37 |
| Adjustments in chemical fertilizer | | | | |
| Increase | 17 | 15 | 0 | 12 |
| Decrease | 35 | 19 | 13 | 24 |
| No change | 48 | 66 | 87 | 64 |
| Pest infestation in crop | | | | |
| Increase | 70 | 65 | 13 | 56 |
| Decrease | 22 | 24 | 45 | 28 |
| No change | 8 | 11 | 42 | 16 |
| Manual weeding | | | | |
| Increase | 50 | 27 | 10 | 33 |
| Decrease | 2 | 5 | 0 | 3 |
| No change | 48 | 68 | 90 | 64 |

The second reason is related to the land allocation process followed by local communities. In China, land and local water resources (irrigation systems, water reservoirs, ponds, etc.) are managed by the local community. Land is owned by the local community and is allocated to individual households, which have usufruct rights. The community may reallocate the land among households as needed. Similarly, the community may manage local water resources differently to deal with specific situations such as drought. The community response to drought thus consists of manipulating these commonly-owned resources.

Farmers are allocated different land types (land with good irrigation, land with poor irrigation, rainfed and nonrice land) mainly for equity reasons. However, this type of land allocation also improves risk management at the household level. Drought may affect production from land with poor irrigation and from rainfed land substantially. If the household had only this type of land, the consequences on household welfare could be severe. The allocation of a portfolio of land types at the household level improves households' ability to better cope with droughts. Land reallocations are, of course, not made in response to individual drought events for efficiency reasons. Instead, the nature of land allocation in a community may partly reflect its long-term response to drought risk.

During drought years, the community also manages local water resources to better meet farmers' needs. Many local water storages have multiple uses such as fishing and agriculture. In the event of drought, the local community may decide to forgo income from fishing and instead allocate water for agricultural use. Even when the management of local water bodies for fishing is contracted out to the private fishing industry, sufficient flexible clauses are normally built into the contract to permit agricultural use of water in the event of drought.

## 5. Drought mitigation strategies and institutional setup

This section provides a critical overview of policies and institutional setup for drought management in China in general and in southern China in particular. A detailed assessment of government policies and strategies for drought mitigation is provided in the first part and institutional arrangements and responses to drought mitigation are described in the latter part. The discussion is based on secondary data as well as information collected from surveys of relevant government departments and research institutes working on agricultural drought at the provincial, county, and township level.

The recurring drought in China is a manifestation of the long-term imbalance in its available water resources and rapidly accelerating demand for water. The problem is not just one of climatic aberrations leading to a shortfall in rains, but that of a wider problem of a general shortage of water. Per capita water availability in China is only about 25% of the world average. The industrial and urban demand for water continues to rise rapidly and this is putting tremendous pressure on the water supply for agricultural uses. The need to supply adequate water for urban and industrial uses tends to loom large in policy debates. It is important to view government policies and strategies for mitigating agricultural drought in this larger context.

China is a huge country and the spatial distribution of water is highly uneven. Northern China has 65% of the farm land but its share of water resources is only 19%, whereas southern China, with 35% of the farm land, has over 80% of the total water resources (Jun and Chen 2001). As a result, drought is a recurrent phenomenon in northern China, resulting in large economic losses. Hence, most of the drought mitigation programs are targeted to northern China. In southern China (the focus of this study), drought is less frequent and less severe.

The drought mitigation strategy of the government of China has both long-term and short-term components. The long-term component includes a broader program for developing water resources, using irrigation more efficiently, developing crop varieties and cropping systems that require less water, and developing drought forecasting and early-warning systems. Short-term responses, implemented during drought years, include cloud seeding for artificial rainmaking, and various forms of relief such as the provision of agricultural inputs and, in the worst cases, direct food distribution.

The Chinese government initiated the Water Resources Development Plan in 1992 to promote sustainable economic and social development (MWR 2003). Since then, the government has adopted a series of measures to improve and strengthen water resources management. These include suitable legislation, institutional reforms in water administration, strengthening of water resource planning, improvements in the operation of water markets, the renovation of age-old water-harvesting structures, and south-to-north water diversion. From 1998 to 2003, the central government invested \$22 billion for the construction of various infrastructures for water resource development. In 2003, the government allocated \$10 billion for this purpose.

Most of the present irrigation facilities were built in 1950-60, and they have deteriorated over time. As a result, these structures are not able to supply water efficiently. Rehabilitating this irrigation infrastructure is an important part of the water resource development strategy.

Improvements in water-use efficiency at the farm level involve the promotion of water-efficient irrigation technologies. Another option is to reduce the overall demand for water by switching to crop combinations and production systems that require less water. An example of this is a shift from the double-rice to single-rice system. Although various economic pressures have encouraged farmers to shift over time from planting two crops of rice per year to only one crop per year, such a change has had an impact on drought avoidance to a certain degree. In double-crop systems, spring rice, which is planted early, generally suffers from drought as rains are not adequate during the crop establishment phase. This crop is hence heavily reliant on irrigation. The area under this early rice crop has decreased over time as farmers have switched to producing only one crop of autumn rice. Such a shift has increased the overall water-use efficiency. In other areas, a shift from rice to water-saving upland crops has been promoted. Similarly, improved rice varieties that can be grown under "aerobic" or nonflooded conditions and associated crop management practices are being made available to farmers. Developing drought-tolerant varieties is another strategy that is being actively followed by research organizations.

China has made substantial progress in developing an early-warning drought forecasting system (Li 2000). A drought monitoring and forecasting system is being developed using remote sensing and GIS. The China National Climate Center is taking the lead role in developing this system, which is a part of the larger weather monitoring and forecasting system for managing both flood and drought.

One of the major short-term responses is cloud-seeding[11] for artificial rainmaking. During drought years, cloud-seeding is practiced in different parts of the country, particularly in northern China. Although the practice started in 1958, it has drawn greater attention and support from local and central governments in recent years. In 2003, over 3,800 rocket launchers, about 7,000 antiaircraft guns, and many airplanes were used for cloud-seeding operations in more than 1,800 counties throughout China. More than 35,000 people were involved and approximately $49 million was invested in the program in 2003 (China Daily 2004/07/26). In 2003, Guangdong Province invested an additional $1 million for research on cloud-seeding equipment and technologies. This technology is still in its development stage in China. More work is needed to solve the scientific and technical problems associated with cloud-seeding to make this practice economically viable.

Relief, included as a part of the "drought-fighting" program, is provided to drought-affected areas. Provision of relief comes under the general umbrella of "Disaster Mitigation Programs." The White Paper on China's Population, Environment, and Development in the 21st Century, developed as part of China's Agenda 21, outlines the major elements of the relief strategy (ACCA21 1994).

[11]Cloud-seeding is a long-practiced technology in China, which uses rockets, planes, and cannons, to fire rain-forming particles, usually silver iodide, into clouds.

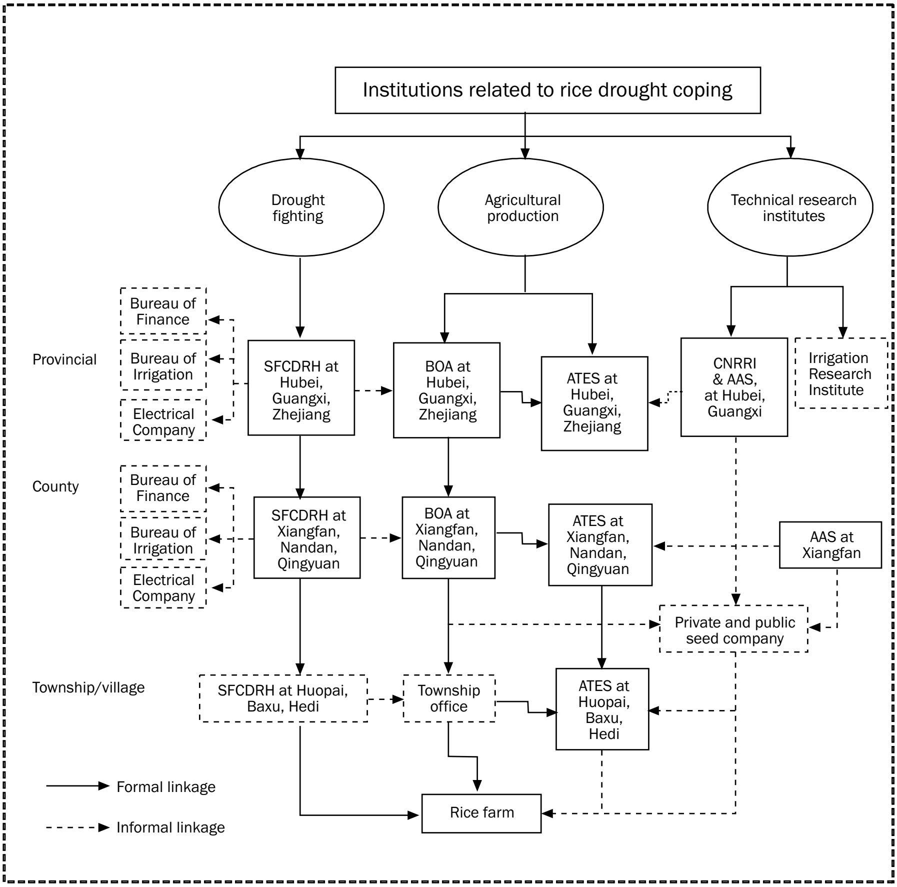



**Fig. 6.8. Linkages among various institutions involved in drought mitigation, southern China.**

The relief activities include rehabilitation of minor irrigation schemes such as community-level ponds, provision of irrigation pumps to affected areas, distribution of subsidized fuel for operating the pumps, and technical assistance for repair and maintenance on the pumps. In addition, fertilizers and seeds are also provided to affected farmers at highly subsidized rates. In extreme cases of drought, the government also distributes drinking water and food grains in affected areas.

The major organizations involved in designing and implementing drought mitigation and relief programs are the Office of the State Flood Control and Drought Relief Headquarters (SFCDRH), Bureau of Agriculture (BOA), Academy of Agricultural Sciences (AAS), Agricultural Technology Extension Stations (ATES), and various agricultural research organizations. All these organizations operate through their provincial, county, and township-level offices (Fig. 6.8).

SFCDRH is a part of the Department of Water Resources Management. SFCDRH is mainly responsible for flood prevention and drought fighting, which is usually co-organized by several government departments, such as the Department of Water Resources Management, Department (Bureau) of Agriculture, Department of Power (Electricity) Management, Department of Finance, Department of Meteorology Services, Department of Civil Affairs, etc. Activities of SFCDRH relate to long-term programs such as water resource development and drought forecasting, as well as short-term programs such as cloud-seeding and distribution of relief.

The Bureau of Agriculture is a provincial and county-level government department in charge of agricultural management. It plans the planting industry, manages the distribution of agricultural inputs, and participates in drought fighting when drought occurs. The Agricultural Technology Extension Station is under the leadership of the BOA. Hence, the BOA is responsible for the extension of agricultural technology.

The Academy of Agricultural Sciences (AAS) is an institute involved in research in agricultural sciences and technologies, and can be categorized into three levels based on the scope of the research and the sources of funds: national level, provincial level, and prefecture or city level. In the study area, three levels of research institutes are involved in rice research. The China National Rice Research Institute (CNRRI), located in Zhejiang Province, is a national-level research institute under the leadership of the Chinese Academy of Agricultural Sciences. The Guangxi Academy of Agricultural Sciences and Hubei Academy of Agricultural Sciences are province-level research institutes. Finally, the Xiangfan Academy of Agricultural Sciences is a prefecture-/city-level research institute. The primary function of AAS is to carry out research on crop cultivation (cropping patterns) and regional trials of crop varieties.

The efforts of these various organizations are channeled through a local government office and the local government chief is the primary person responsible for implementing drought mitigation programs (Fig. 6.8). Drought mitigation activities are thus directly led by the highest local administrative official and the work of all line agencies is coordinated and integrated at this level. This institutional setup helps respond to local needs efficiently in a coordinated and integrated manner.

## 6. Conclusions and recommendations

The results of the study indicate that, in the three southern provinces of China included in this study, drought occurs with a probability of 10–30%. Drought occurs during both the planting and reproductive phases of the growth of the rice plant. Rice production losses at the aggregate (county or province) level, however, were statistically insignificant. The loss estimates obtained here using the time-series data on production and rainfall thus differ from the loss estimates of 3–5% derived in earlier studies (Dey and Upadhyaya 1996, Lin and Shen 1996). This variation in the results could be due to differences in the approach used. The previous studies were based on experimental and/or subjective assessment of the percentage yield loss during drought years. In the current study, a rainfall-based definition of drought is used and actual production data at the county and province levels over time are correlated with rainfall. By using the official recorded rainfall and production data, the current study avoids the potential biases that may exist in the experimental/subjective assessment used in the earlier studies.

Despite a low estimate of production loss at the provincial level, the losses reported by the affected households were found to be substantial. Farmers reported production losses of major crops such as rice, wheat, and maize, with the average production losses for rice during a drought year being 44% compared with those of a normal year. Drought resulted in both area and yield losses for rice, with the magnitude of loss being dependent on the land type. Losses were lowest in land with good irrigation and highest in poorly irrigated areas.

This large loss estimated at the household level is not inconsistent with the lack of evidence of substantial loss at the aggregate level. It merely implies that drought effects are localized and not widespread.

Farmers attempted to cope with production losses by deploying various coping mechanisms. Adjustment in cropping pattern was one important coping mechanism. When drought occurred early in the season, farmers reduced the area of rice and substituted sesame, soybeans, and other crops for rice in order to reduce losses in total farm output. Similarly, farmers expanded the area under winter crops such as wheat and oilseeds to compensate for losses in rice production. Delayed transplanting, replanting of rice, reducing the fertilizer dose, and increasing weeding intensity were some other commonly deployed coping mechanisms to reduce losses.

An important coping mechanism available to rice farmers in the study area is to augment the water supply through additional pumping of water during drought years. During the survey, farmers reported that this is a commonly deployed coping mechanism in Hubei and Zhejiang, where farmers have access to irrigation. However, this coping mechanism entails an additional cash cost for pumping water. With two additional pumpings during drought years, the additional cost to farmers is approximately \$90–200 per ha. For resource-poor farmers, this additional cash cost represents a heavy burden.

The results indicate that drought in the study area does not directly lead to a consumption decline. In most cases, farmers are able to maintain their consumption level. They are able to do so by earning additional nonfarm income. The healthy growth of the nonfarm sector has enabled farmers to cope with the consequences of drought better.

An important way the local community is able to assist farmers during drought is through the management of community-owned land and water resources. Agricultural land is allocated to households in an equitable manner in proportion to the family size and other criteria. When allocating land, households obtain a portfolio of well-irrigated, poorly irrigated, and rainfed land. This process of allocating the most important resource base of agricultural households helps them cope better with climatic risk by reducing the overall production risk. Although there may be some efficiency costs associated with such practices, they do seem to provide some degree of protection against drought.

Local water resources (such as canals, reservoirs, and small ponds) are managed by the local community in China. This gives communities flexibility to respond to community needs speedily and more efficiently in times of need such as drought relative to when water resources are managed centrally. Local communities in the study area were able to divert multiple-use water resources for agricultural use in drought years through mutually agreed-upon mechanisms. Such arrangements also help distribute the burden of adjustment to drought among households in a more equitable manner than when such resources are privately or centrally owned.

The government of China has established institutional mechanisms to coordinate its multidimensional efforts for drought mitigation and relief. The inputs of several agencies involved are coordinated by a national-level organization but the actual implementation of the program is led by the local government, which serves as the main point where these various efforts are integrated. The major thrust of the program is the overall development of water resources, improved irrigation technologies for higher efficiency, improved crop production technologies, and provision of relief.

Given the overall water scarcity in China, an integrated approach involving further expansion of irrigation, rehabilitation of existing irrigation infrastructure, improving irrigation efficiency, improving water use through community-managed ponds, improving crop/variety tolerance of drought, and a shift toward the aerobic mode of production are needed for ultimate protection against drought. Important progress in this regard is being made, but a comprehensive master plan is needed to provide a framework for the proper integration of these various strategies. One important area of policy intervention is to raise the price of water to discourage its wasteful use. Detailed studies are needed to analyze the efficiency and equity effects of changes in water prices and the institutional setup needed for implementation of an effective water-pricing policy.

Policy measures are also needed to ensure that the poorer segments of the community do not bear a disproportionate share of the burden of drought. Farmers who are economically better off are able to rely on nonfarm income to cope with drought, while this avenue appears not to be easily available to the poor. Their lack of skill and education may be a factor hindering participation in the nonfarm sector. Assistance to this group of farmers to develop such capacity would be desirable. Similarly, targeted assistance in terms of food aid, preferential treatment for such groups for employment in public-sector work programs and micro-credit, and consumption loans can also help them cope with drought better.

Improvement in drought-forecasting techniques can help societies to be better prepared to deal with the consequences of drought. The farm-level cost of adjustment can also be lowered if farmers have access to drought forecasts in a timely manner. For example, if farmers have a fairly reliable and timely forecast of drought, they may avoid the cost of planting a crop that is likely to fail by planting another substitute crop. Input management strategies can be similarly adjusted to avoid costly losses. More work is needed for the generation of reliable forecasts of drought and timely provision of such forecasts to farmers.

Drought relief activities are coordinated by the State Flood Control and Drought Relief Headquarters, while the Ministry of Civil Affairs is in charge of national general relief activities. While watershed management issues for providing longer-term protection from flood and drought are better addressed in an integrated manner, lumping of the relief activities related to these two different types of disasters is less desirable. The impact of flood is highly visible in terms of damage to infrastructure and loss of life, whereas the effects of drought are slow but long-lasting. The nature of relief required and the targeting process, hence, would have to be different. In addition, financial resources available to a single agency in charge of dealing with both kinds of relief are likely to be used for flood relief because of its highly visible nature. Drought relief could be more effectively provided if a separate specialized agency with its own earmarked budget were established.

Increasing income diversification of the Chinese rural economy is an important factor that has provided considerable protection against drought. Policies that reinforce this process of change will not only provide protection against drought but also help address many of the problems related to structural transformation of the rural economy. Thus, increased investments in education, vocational training, and rural marketing infrastructure, and provision of better access to credit will help improve farmers' ability to cope with drought and other sources of risk better. Such investments also promote general growth in the rural economy.

## References


ACCA21 (Administrative Center for China's Agenda 21). 1994. China's Agenda 21: white paper on China's population, environment, and development in the 21st century. Haidian District, Beijing (China): The Administrative Center for China's Agenda 21. Online at www.acca21.org.cn.

AFP (Agence France-Presse). 2005/12/29. Drought threatening fresh water supplies in southern China. Paris (France): AFP.

AP (Associated Press). 2000/06/28. China battles drought with $48 million emergency package. News story. New York, N.Y. (USA): The Associated Press.

The Boston Globe. 1999/03/31. Chinese drought hits wheat areas. A news story. Boston, Mass. (USA): The Globe Newspaper Company. Online at www.boston.com.

Brown L. 1994. Who will feed China. World Watch. September/October 1994.

China Daily. 2000/06/04. China battling severe drought. A news report. China People's Daily Newspaper. Beijing (China): China Internet Information Center.

China Daily. 2001/05/06. Agro experts develop water-saving rice in China. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2001/05/28. Farmers developing water-saving cultivation. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2001/06/07. Crops crippled by 100-day drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2001/06/21. China seeks to relieve severe drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2001/12/21. Cash for water conservation. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.china.org.ch/english/SO-e/24060.htm.
China Daily. 2002/02/21. Dangerous reservoirs undergo upgrading. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.china.org.ch/english/2002/Feb/27244.htm.
China Daily. 2002/03/05. Spring drought looms for China. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2002/05/09. Severe drought hits south China. A news report. China Daily. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2003/03/27. Farmers hit by severe drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2003/08/01. Cloud seedng works in drought-hit regions. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2003/08/05. Worst drought in 65 years strikes southeast China. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2003/08/06. East China city hit by severe drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2003/08/14. Disaster drought hits lives of 90 million. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2004/03/31. Save the nation from drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2004/07/24. Cloud seeding helps alleviate drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2004/07/26. Cloud seeding eases drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2004/07/30. Drought strikes southern China. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2004/08/12. Drought may prompt areas to seed clouds. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.
China Daily. 2004/08/23. Artificial rainfall increased to fight drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China daily. 2004/11/04. China drought withers crops, energy, tourism. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2004/11/22. Worsening drought parches Guangdong. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2004/12/02. Water diversion planned to beat drought. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2004/12/22. Drought may hit hard next year. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2005/04/04. Drought affects plowing season. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2005/04/11. Guangdong experiences worst drought in 50 years. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

China Daily. 2005/08/12. Drought hits 7.6 million people across China. A news report. China Daily—a national English-language newspaper in China. Beijing (China): China Internet Information Center. Online at www.chinadaily.com.cn.

Dey MM, Upadhyaya H K. 1996. Yield loss due to drought, cold, and submergence in Asia. In: Evenson RE, Herdt RW, Hossain M, editors. Rice research in Asia: progress and priorities. CAB International in association with the International Rice Research Institute. Los Baños (Philippines): International Rice Research Institute.

FAO (Food and Agriculture Organization of the United Nations). 1997. The impact of El Niño and other weather anomalies on crop production in Asia. A special report. Global Information and Early Warning System on Food and Agriculture. Economics and Social Department. Rome (Italy): FAO.

FAO (Food and Agriculture Organization of the United Nations). 2000. Severe weather disturbances seriously affect crop and food supply prospects in Asia and displace millions. Special Reports and Alerts 311. Global Information and Early Warning System on Food and Agriculture (GIEWS). Economics and Social Department. Rome (Italy): FAO.

FAO (Food and Agriculture Organization of the United Nations). 2001. Food crops and shortages in Asia. Global watch. Global Information and Early Warning System on Food and Agriculture (GIEWS). Economics and Social Department. Rome (Italy): FAO.

Guangxi Statistical Yearbook. 2002. Guangxi Statistical Bureau, China Statistical Press. (In Chinese.)

Hubei Statistical Yearbook. 2002. Hubei Statistical Bureau, China Statistical Press. (In Chinese.)

Jun X, Chen YD. 2001. Water problems and opportunities in the hydrological sciences in China. Hydrol. Sci. 46(6):907-921.

Li K. 1999. Drought disaster research and prevention in China. China: Henan Science & Technology Press. (In Chinese.)

Li K. 2000. Drought early warning and impact assessment in China. In: Wilhite DA, Shivakumar MVK, Wood DA, editors. Early warning systems for drought preparedness and drought management. Proceedings of an expert group meeting, Lisbon, Portugal, 5-7 September 2000. Geneva (Switzerland): World Meteorological Organization. p 111-130

Lin JY, Shen M. 1996. Rice production constraints in China. In: Evenson RE, Herdt RW, Hossain M, editors. Rice research in Asia: progress and priorities. CAB International in association with the International Rice Research Institute (IRRI). Los Baños (Philippines): IRRI.

Lohmar B, Huang G, Wang J, Dawe D, Rozelle S. 2003. China's agricultural water policy reforms: increasing investment, resolving conflicts, and revising incentives. Agriculture Information Bulletin No. 782. Economic Research Service. Washington, D.C. (USA): United States Department of Agriculture.

MWR (Ministry of Water Resources of China). 2003. China country report on sustainable development-water resources. Ministry of Water Resources, People's Republic of China. Beijing (China): Ministry of Water Resources.

MWR (Ministry of Water Resources of China). 2004. Water resources in China: special issues published on 2 August 2004. Beijing (China): MWR. Online at www.mwr.gov.cn.

NBS (National Bureau of Statistics of China). 2005. China statistical yearbook 2004. Beijing (China): China Statistics Press. Online at www.stats.gov.cn/english/.

NDRC (National Development and Reform Commission). 2005. China's water conservation technology policy outline (2005-04). Policy Release No. 17. Beijing (China): NDRC.

Pandey S, Behura DD, Villano R, Naik D. 2000. Economic costs of drought and farmers' coping mechanisms: a study of rainfed rice systems in eastern India. IRRI Discussion Paper Series 39. Los Baños (Philippines): International Rice Research Institute. 35 p.

People's Daily. 2001/11/06. Efforts urged for drought relief in North China. A news report. People's Daily Online English Edition. Beijing (China): People's Daily Online. Online at http://english.peopledaily.com.cn.

People's Daily. 2001/10/31. Diversion to relieve drought. A news report. People's Daily Online English Edition. Beijing (China): People's Daily Online. Online at http://english.peopledaily.com.cn.

People's Daily. 2001/11/30. Millions of Chinese survive unprecedented drought. A news report. People's Daily Online English Edition. Beijing (China): People's Daily Online. Online at http://english.peopledaily.com.cn.

People's Daily. 2002/08/14. One million facing drought in China's Shandong. A news report. People's Daily Online English Edition. Beijing (China): People's Daily Online. Online at http://english.peopledaily.com.cn.

ReliefWeb. 2000/06/15. Situation report on drought, floods and earthquake. The People's Republic of China No. 1. Situation report. United Nations Office for Coordination of Humanitarian Affairs. Online at www.reliefweb.int/.

Rosegrant M, Cai X. 2003. Market adaptations to increased water prices in China: the effects on water demand and rice production. In: Mew TW, Brar DS, Dawe D, Hardy B, editors. Rice science: innovations and impact for livelihood. Proceedings of the International Rice Research Conference, 16-19 September 2002, Beijing, China. Beijing (China): International Rice Research Institute, Chinese Academy of Engineering, and Chinese Academy of Agricultural Sciences. p 847-868.

Xinhua News Agency. 2001/05/29. Serious drought hits Shanxi province. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2001/06/28. Northeast China fights drought. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2002/03/18. North China battles water shortages in drought. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2002/05/04. Rare drought hits south China province. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2003/03/12. South China region to relieve drought with artificial rain. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2003/08/04. Vice premier urges good job in drought relief. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2004/08/14. Drought strikes southern China. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2004/11/11. China fights drought in the south. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2004/11/12. Drought in south China causes great losses. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2004/12/23. Drought may hit hard next year. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhua net.com.

Xinhua News Agency. 2005/02/26. Hainan suffers serious drought. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Xinhua News Agency. 2005/10/11. Drought haunts 2 million people in south China. A news report. Xinhua online English edition. Beijing (China): Xinhua News Agency. Online at www.xinhuanet.com.

Yuanhua L, Wenjin N, Chongde C. 2003. Strategies for managing water scarcity in rice production areas in China. In: Mew TW, Brar DS, Dawe D, Hardy B, editors. Rice science: innovations and impact for livelihood. Proceedings of the International Rice Research Conference, 16-19 September 2002, Beijing, China. Beijing (China): International Rice Research Institute, Chinese Academy of Engineering, and Chinese Academy of Agricultural Sciences. p 507-518.

Zhejiang Statistical Yearbook. 2002. Zhejiang Statistical Bureau, China Statistical Press. (In Chinese.)

Zhu D. 2000. Bridging the rice yield gap in China. In: Papademetriou MK, Dent FJ, Herath EM, editors. Bridging the rice yield gap in the Asia-Pacific region. Food and Agriculture Organization of United Nations (FAO). Bangkok (Thailand): Regional Office for Asia and the Pacific.

## Notes

*Authors' addresses:* S. Ding, School of Business Administration, Zhongnan University of Economics and Law, No.1, South Nanhu Road, Hongshan District, Wuhan, 430073, China; C. Chuanbo, College of Agricultural and Rural Development, Renmin University of China, 59, Zhongguancun Dajie, Haidian District, Beijing, 100872, China; H. Bhandari, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines, currently with Japan International Research Center for Agricultural Sciences, 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan; S. Pandey, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines.

*Acknowledgments:* This research project received financial support from the Rockefeller Foundation (Grant No. 2001 FS 129) and the National Natural Sciences Foundation of China (Grant No. 70273013). We are thankful to both organizations for their funding support.

We acknowledge the technical support from Dr. Zhang Qifa (academician of the Chinese Academy of Sciences) of Huazhong Agricultural University, Dr. Luo Lijun, Mr. Gu Xiaojun, Mr. Yu Xinqiao, and Mr. Mei Hanwei of the Shanghai Agrobiological Gene Center, Mr. Yang Wanjiang from Zhejiang University, and Dr. Chen Yuping from the Zhongnan University of Economics and Law.

The fieldwork was conducted by postgraduate students Chen Fengbo, Yi Hongmei, Tong Yuying, Luo Xiaofeng, and Jie Ziping from Huazhong Agricultural University, and Li Jianfeng from Zhejiang University. Support for fieldwork was provided by Yu Huaqiang and Li Youming from Xiangfan Academy of Agricultural Sciences, Li Daoyuan and Liang Yaomao from Guangxi Academy of Agricultural Sciences, and Xue Shiyu from Lishui Institute of Agricultural Sciences, Zhejiang. Similarly, assistance was provided by Pang Zhengsheng, Liu Jianhua, Chen Yufeng, Pang Hualu, Zhou Kaiping, Zhang Sisong, Liu Fahe, Yu Guixian, and Wang Jianwei from the Agricultural Bureau; Li Lin and Fu and Wang Yun from the Drought-fighting Headquarters; Huang Moucai, Wang Shixiang, Wei Mengjun, Qin Shenqian, and Rong Feng from the Nandan County government; Qi Huaxiong from the Hubei Academy of Agricultural Sciences; Tang Shaoqing from China Rice Research Institute; and Wu Tongxin, Zheng Shaoping, and Liu Jiaquan from the Qingyuan County government.

We express our gratitude to 153 farm households in the counties of Xiangyang, Nandan, and Qingyuan, from the three provinces, who patiently answered questions during interviews.

CHAPTER 7
# Summary and recommendations

S. Pandey and H. Bhandari

An important feature of this study is a cross-country comparative analysis of the economic consequences of drought and farmers' coping mechanisms. The three countries included in the study (China, India, and Thailand) differ in agroclimatic conditions, rice production systems, level of economic development, and institutional setup under which agricultural production takes place. The earlier chapters included results of detailed analyses based on both aggregate- and farm-level data. This chapter provides an overall synthesis/summary of the empirical findings of the study and a set of recommendations for more effective drought management.

## 1. Summary

### 1.1 Drought characteristics and production instability

The analysis of monthly rainfall data for the period 1970-2003 indicated that drought is a regular phenomenon in the regions included in the study in all three countries. The probability of drought varies in the range of 0.1 to 0.4, with the probability being higher in eastern India relative to southern China and northeast Thailand (Fig. 7.1). The probability of late-season drought is higher than that of early-season drought generally. Late-season drought is also found to be spatially more covariate than early-season drought. As rice yield is more sensitive to drought during flowering/grain-filling stages (i.e., during the late season, according to the definition used here), late-season drought is thus likely to have a larger aggregate production impact than early-season drought.

The temporal instability in rice production as measured by the de-trended coefficient of variation of rice yield was found to be higher in eastern India than in the other regions. The nature of instability is typically illustrated by the yield trend in Orissa (Fig. 7.2). Such a high level of instability over the whole state (with an average rice area of 4.5 million ha) is indicative of a high frequency and covariate nature of drought. The corresponding coefficients of variation for southern China and northeast Thailand were much lower (Table 7.1), indicating that droughts in these regions are

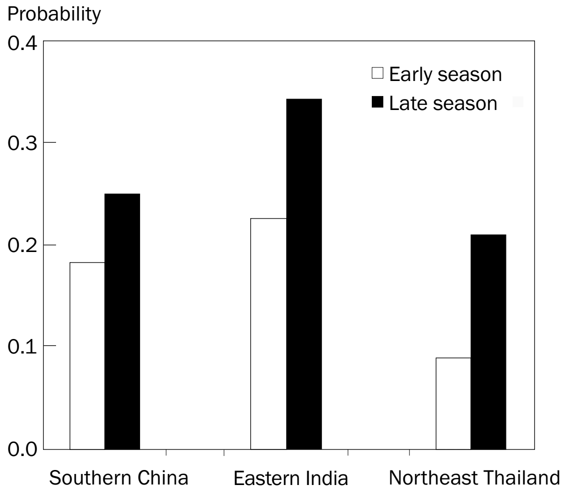



**Fig. 7.1. Estimated probability of early- and late-season drought in southern China (1982-2001), eastern India (1970-2000), and northeast Thailand (1970-2002).**

not covariate spatially, with their effects being limited to some pockets. Given the nature of the temporal variability, the aggregate impact of drought on production is likely to be higher in eastern India relative to the other two regions.

## 1.2 Production losses

Drought results in losses in the production of rice and other crops that are grown during the rice season and of subsequent nonrice crops grown using residual soil moisture. The estimation of aggregate production losses involved the analysis of published temporal data on rainfall and crop production. Actual crop production data over a run of years covering both drought and nondrought years were used in this study as opposed to the usual approach in earlier studies that used farmers' and/or researchers' subjective estimates (Widawsky and O'Toole 1990, Hossain 1996, Gypmantasiri et al 2003). The details of the approach are described in Chapter 3. Because of the use of aggregate time-series data on production, the loss estimates are likely to reflect the reality better than the subjective estimates based on small areas used in these earlier studies.

The estimated average loss during drought years using the dummy variable model for the three states of eastern India is 5.4 million tons (Table 7.2). This is much higher than for northeast Thailand (less than 1 million tons) and southern China (around 1 million tons but not statistically significant). The loss (including any nonrice crops) during drought years is thus 36% of the average value of production in eastern India. This indeed represents a massive loss during drought years (estimated at $856 million).

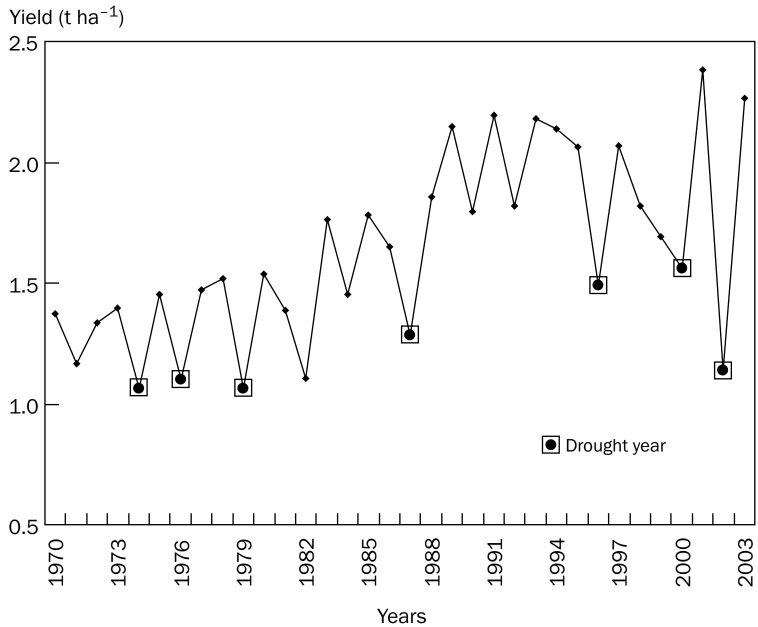



**Fig. 7.2. Trends in rice yield and major drought years, eastern India (Orissa), 1970-2003.**

**Table 7.1. Coefficient of variation of rice area, yield, and production, 1970-2003.[a]**

| Rice | Southern China | Eastern India | Northeast Thailand |
|---|---|---|---|
| Area | 3 | 2 | 7 |
| Yield | 4 | 17 | 9 |
| Production | 5 | 18 | 10 |

[a]CVs were estimated based on secondary data of study provinces/states. CVs for China were estimated using quadratically de-trended data. CVs for India and Thailand were estimated using linearly de-trended data.
Data sources:
China: NBS (2005).
India: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).
Thailand: OAE (2004).

As droughts do not occur every year, the above estimate of production loss needs to be averaged over a run of drought and nondrought years to get the annual average loss estimate. Again for eastern India, this represents the annual average loss of $162 million (or 6.8% of the average value of output). For northeast Thailand and southern China, the losses were found to be much smaller and averaged less than $20 million per year (or less than 1.5% of the value of output).

The estimates thus indicate that, at the aggregate level, production losses are much higher for eastern India than for the other two regions. Lower probability of

**Table 7.2. Estimated value of crop production losses due to drought using rainfall-based drought years, 1970-2002.[a]**

| Country | Drought years | | | Annual | |
|---|---|---|---|---|---|
| | Quantity of rice production losses (million t) | Value of crop production losses[b] (million US$) | Ratio of loss to average value of production (%) | Value of crop production losses[b] (million US$) | Ratio of loss to average value of production (%) |
| Southern China | 1.2 | 133 | 3 | 16 | 0.4 |
| Eastern India | 5.4 | 856* | 36 | 162 | 7.0 |
| Northeast Thailand | 0.7 | 85* | 10 | 10 | 1.2 |

[a]The values were estimated based on secondary data of study provinces/states. [b]The value of production losses was estimated using both rice and nonrice crops for India, whereas only rice crops were used for China and Thailand. *means statistically significant at the 10% probability level.
Data sources:
China: NBS (2005).
India: NCAP-IRRI eastern India rice database (2002) and INDIAAGRISTAT (2005).
Thialand: OAE (2004).

drought, smaller magnitude of loss during drought years, and less covariate nature of drought together have reduced production losses at the aggregate level in the other two regions relative to eastern India.

Such a massive reduction in rice production in eastern India is bound to result in further second-round losses in agricultural GDP. This multiplier effect is estimated to be 0.32%.[1] Thus, the additional loss in agricultural GDP during drought years is likely to be $237 million. Total losses (including the production loss of $856 million during drought years) thus exceed a billion dollars.

## 1.3 Household-level impact and coping mechanisms

A detailed analysis of the household-level impact of drought was conducted using farm survey data. Drought-affected households suffered production losses of 44–71% (Table 7.3). Even in southern China and northeast Thailand, where aggregate production losses were small, production losses for the households affected by drought were substantial. Production losses resulted from both yield loss and area loss. The loss in yield, however, accounted for the major share of production losses.

The effect of drought on production also varied according to land type. This is illustrated by the farm-level data from eastern India (Table 7.4). Production losses were found to be substantially higher in upper terraces (or uplands) that typically

[1]The multiplier effect was estimated by regressing agricultural gross domestic product (AGDP) with the de-trended value of rice production. Time-series data covering 1993-2003 were used for this purpose. The coefficient implies that a 10% reduction in rice production in eastern India is associated with a 3.2% decline in the total value of agricultural goods and services produced.

**Table 7.3. Percentage change in rice area, yield, and production among sample farm households in drought years compared with normal years.**

| Rice | Southern China | Eastern India | Northeast Thailand |
|---|---|---|---|
| Area | –19 | –36 | –21 |
| Yield | –31 | –54 | –45 |
| Production | –44 | –71 | –56 |

**Table 7.4. Percentage change in rice area, yield, and production among sample farm households in drought years compared with normal years, by land type, eastern India.**

| Rice | Land type | | |
|---|---|---|---|
| | Upland | Midland | Lowland |
| Area | –72 | –40 | –17 |
| Yield | –70 | –65 | –56 |
| Production | –92 | –81 | –62 |

have lower moisture-holding capacity than in mid or lowland fields. This differential impact by land type indicates the need to target technological interventions for drought mitigation according to land type.

The household-level impact of drought presented here is based mainly on the study in eastern India. Relative to eastern India, impacts in northeast Thailand and southern China were found to be small and, hence, are not discussed here.

In eastern India, the drop in agricultural income during drought years was estimated to be in the range of 40–80% of normal-year income. This results from a drop not only in farm production but also in wage income earned as farm labor. Farmers attempted to reduce the loss in agricultural income during drought years by seeking additional employment in the nonfarm sector. This mainly included employment as wage labor in the construction sector for which farmers often migrated to distant places. The additional earning from nonfarm employment, however, was clearly inadequate to compensate for the loss in agricultural income, thus resulting in a drop in total income in the range of 24–58%.

Farmers relied on three main mechanisms to recoup this loss in income: selling productive assets (such as bullocks and farm implements), using savings, and borrowing. These adjustment mechanisms helped recover only 6–13% of the total loss in income. Compared to normal years, households still ended up with a lower level of income despite all these adjustments. The drop in overall income averaged 20–50% of normal-year income. Thus, all the different coping mechanisms farmers deployed were found to be inadequate to prevent a shortfall in income during drought years.

The above analysis provides a general picture of the overall impact of drought on farm income. This impact is likely to differ across farm size groups given the differences in income strategies. Crop production loss is expected to have a smaller proportionate effect on the income of smaller farm size categories as they derive relatively less income from crop production. The proportionate loss in the total income of small and marginal farmers was indeed less than that of the medium and large farm size categories. For example, the total loss in income of small and marginal farmers was found to be 17–42%, whereas that of medium and large farmers was 25–67%.

Despite this lower proportionate loss, the welfare effect of income is likely to be more severe for small and marginal farmers who earn a much lower level of income even during normal years. For example, marginal farmers earned only 16–25% of the income of larger farm size categories during normal years. The marginal and small farm size groups are thus more likely to "fall back" into poverty during drought years than the other farm size groups.

The incidence of poverty increased substantially during drought years. The estimates indicate that almost 13 million additional people "fell back" into poverty as a result of drought (Chapter 4). This is a substantial increase in the incidence of poverty and translates into an increase in rural poverty at the national level of 1.8 percentage points. In addition to the rise in the incidence of poverty, poor people get pushed even deeper into poverty (Fig. 7.3). Some of the increase in poverty may be transitory, with households being able to climb out of poverty on their own relatively smoothly. However, other households whose incomes and assets fall below certain threshold levels may end up joining the ranks of the chronically poor (Barrett 2005). As indicated in Chapter 4, households with small farm sizes, with proportionately more area under drought-prone upland fields, and with a smaller number of working-age members are more vulnerable to such adverse income consequences of drought.

Since rice is the staple food, a loss in its production can be expected to result in major adjustments in consumption. Such adjustments may range from reduced sale of rice, reduced quantity retained as seeds for the following year, increased amounts purchased, substitution of other crops for rice, supplementation of food deficit by other types of food not normally consumed, and, in the worst-case scenario, a reduction in consumption.

Farmers made all these types of adjustments to a varying degree. One of the major effects of production loss is a severe reduction in sales, the quantity of seeds kept for the subsequent year, and the quantity stored for future use. The quantity of rice sold during drought years decreased by 82–98% compared with a normal year. This reduction in the marketed quantity would obviously have a price effect in the local market, which, if not counteracted by an inflow of grains from other areas, will result in an overall reduction in consumption per capita. This price effect may help stabilize the income of those who are rice sellers. However, such price increases will have a regressive impact on the welfare of poor laborers and marginal farmers who spend a larger share of their income on rice purchases.

Farmers even reduced (by 40–93%) the quantity retained as seeds for planting during the subsequent year. This kind of adjustment may be considered to be a rather

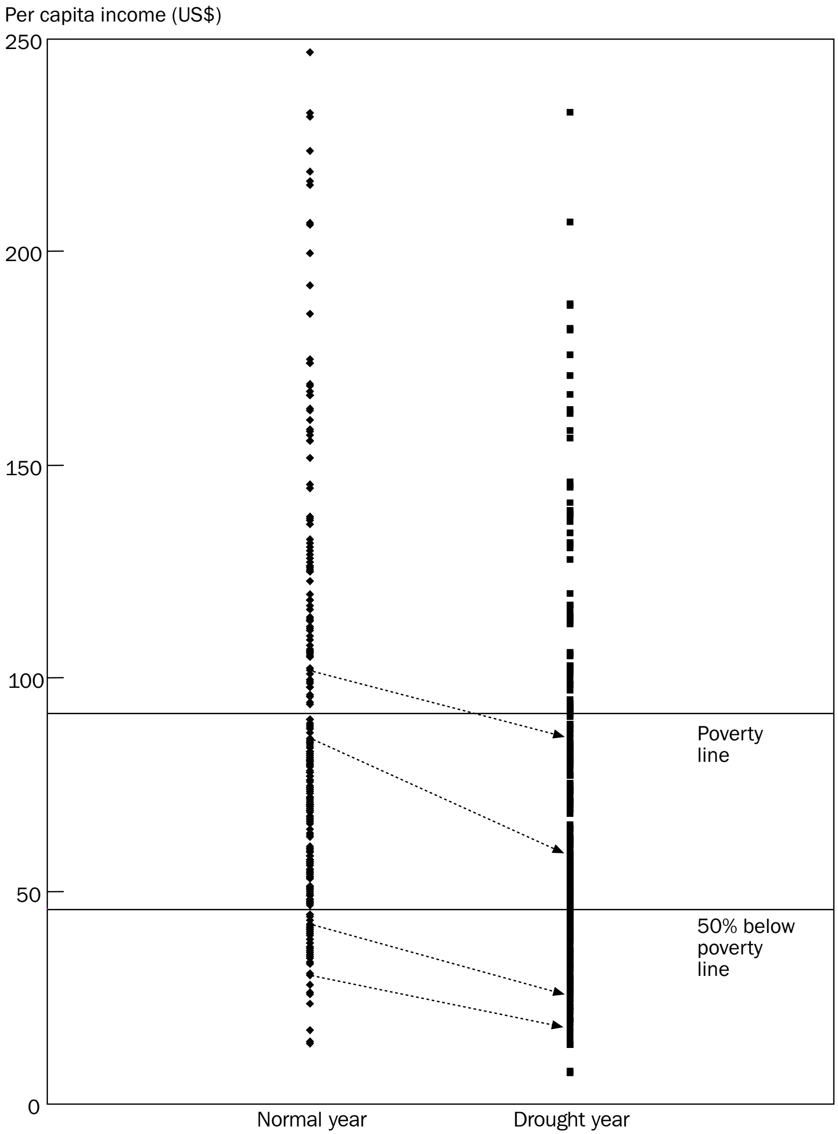



**Fig. 7.3. Effect of drought on incidence and severity of poverty, Jharkhand, India (each dot refers to a household).**

desperate response since production during the subsequent year will almost certainly suffer when grains meant for seeds are consumed.

Despite these various adjustments, most farmers were unable to maintain consumption at the predrought level. They reduced both the number of meals taken per day as well as the quantity consumed per meal. As a result, the average number of meals taken per day dropped from close to three to close to two, with 10–30% of the households reducing their frequency of food intake to one meal per day. A large proportion (60–70%) of the households also reduced the quantity of food consumed per meal. In addition, households consumed other "inferior" food items that were not normally consumed.[2]

Forced adjustment in expenditure is a logical consequence of income loss. Reduced expenditure on some nonessential items such as clothing and social functions may not have many welfare implications. However, farmers often reduce expenditure even on essential items such as food and medical treatment. Such expenditure cuts are most likely to result in adverse short- and long-term consequences. More than 50% of the farmers also reported curtailing children's education. This occurs for three reasons. First, parents may be unable to meet the recurring cost of education, although such expenditure may be small in absolute amount. Second, adolescent children may be pulled out of school to work as labor to augment family income. Third, children leave school to accompany their migrant parents. Such parents are unlikely to be able to re-enroll the children in the new location due to the seasonal nature of migration. Lack of familiarity with the new location and poor social integration of the seasonal migrant community with local residents may aggravate the problem. Whatever the reason, interruption and/or discontinuation of children's education is a disinvestment in human capital that will most definitely reduce their future earning potential in most cases. Thus, an important pathway for escape from poverty may be foreclosed as a result of drought.

Relative to eastern India, farmers in southern China and northeast Thailand do not seem to suffer such a strong negative consumption impact of drought. The major features of coping mechanisms and household-level impact in these three regions are summarized in Table 7.5. Production losses during drought years translate into consumption losses despite the deployment of a range of coping mechanisms in eastern India. The major coping mechanisms deployed to reduce income shortfall include migration, sale of draft animals, and borrowing. However, income generated through these mechanisms is not adequate to compensate for the loss—hence, farmers are forced to reduce consumption. On the other hand, sale (or mortgage) of land is not practiced in southern China and northeast Thailand in response to drought. In the case of China, land is not individually owned—hence, no sale takes place. In Thailand, farming is mechanized to a considerable extent; therefore, the sale of draft animals is not deployed as a coping mechanism. Instead, income smoothing takes place mainly through reliance on income from diversified sources such as nonrice farm production and nonfarm activities in both of these regions. In-crop adjustments in rice production and crop substitution during drought years do not play significant roles in coping with drought in all three regions. Farmers mostly seem to follow a set of major cropping practices with few adjustments in the event of drought.

[2]Such consumption items include wild flowers and fruits, wild roots and tuber crops (*konda*), wild leaves and vegetables, Kendu fruits, boiled Mahua flower, minor millets, broken rice, and boiled maize.

**Table 7.5. Major drought-coping mechanisms of farm households.**[a]

| Drought-coping strategy | Southern China | Eastern India | Northeast Thailand |
|---|---|---|---|
| Migration | + | ++ | + |
| Asset sale | | | |
| Livestock | 0 | ++ | 0 |
| Land | 0 | + | 0 |
| Borrowing | 0 | ++ | + |
| Consumption decline | 0 | + | 0 |
| Expenditure on social functions, medical treatment, and children's education | 0 | – | 0 |
| Use of cash and kind savings | + | + | + |
| Use of social network | + | ++ | + |
| Employment through food-for-work program | 0 | + | 0 |
| Artificial rain-making | + | n.a. | + |

[a]– means a decrease, + means an increase, and 0 means no change. Double marks imply a larger change while a single mark implies a marginal change. n.a. means not applicable.

**Table 7.6. Percentage share of rice and nonrice income in total income of farm households.**

| Income source | Southern China | Eastern India | Northeast Thailand |
|---|---|---|---|
| Rice income | 22 | 40 | 21 |
| Nonrice farm income | 32 | 22 | 28 |
| Nonfarm income | 46 | 38 | 51 |

In the case of eastern India, rice accounts for around 40% of the total household income (Table 7.6). The share of rice in the total household income in southern China and northeast Thailand is about half that in eastern India. Eastern Indian farmers thus lose proportionately more income during drought years. Due to limited diversification of farm income, which is generated mainly from rice, the household-level consequences of drought in eastern India are thus more severe relative to the other two regions. In both northeast Thailand and southern China, agricultural income has become more diversified away from rice toward commercial field crops that are less sensitive to drought than rice. In addition, the share of nonfarm income in total income is much higher. Thus, a more commercialized agriculture and a greater diversification of income seem to have contributed to a smaller consumption consequence of drought in southern China and northeast Thailand relative to eastern India by weakening income correlations and improving the effectiveness of coping mechanisms. The effect of these factors on household-level impact is stylized in summary form in Figure 7.4.

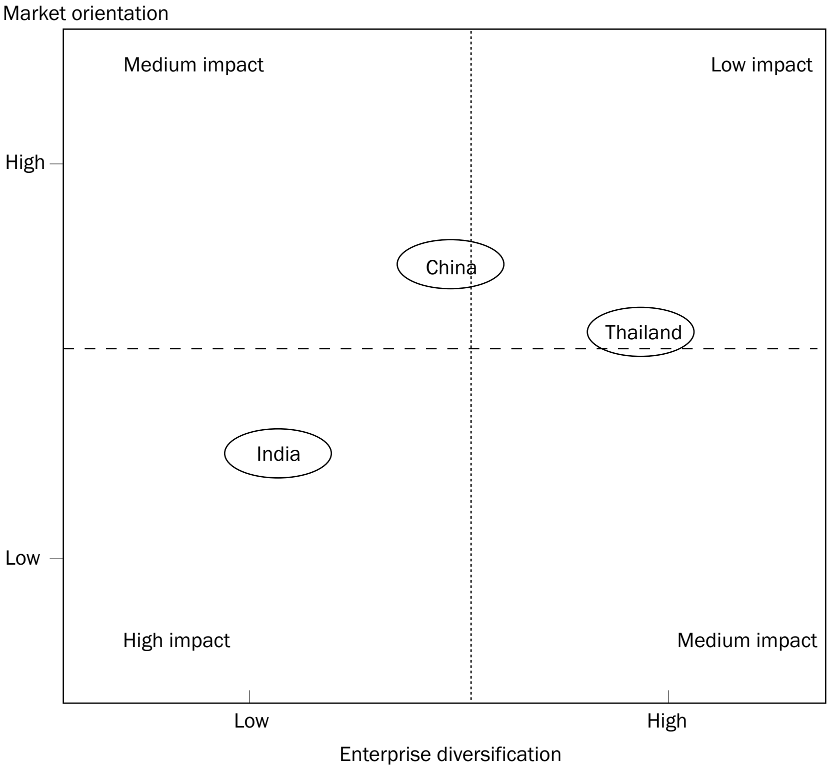



**Fig.7.4. Household-level consequences of drought.**

## 1.4 Overall economic costs of drought

The total economic costs of drought include the value of production losses during drought years, the ex ante cost associated with the opportunity loss resulting from a lower average productivity and the use of conservative practices, the cost of drought relief provided by the government and other agencies,[3] and the cost of mitigation programs implemented to reduce production losses. The average annual cost for the three states of eastern India included in this study was found to be in the neighborhood of \$400 million (or 11% of agricultural GDP). The share of the value of production losses in this total is around 40%. Overall, the costs of drought are a substantial proportion of the agricultural value added in eastern India.

Relative to eastern India, the economic costs in southern China and northeast Thailand are small, in both absolute and relative terms. Production losses at the aggregate

[3]Although this is a transfer payment and does not represent a true economic cost, opportunity losses may be associated with the use of scarce capital for providing relief.

level in these two regions are small due to the lower frequency and less covariate nature of drought. In addition, the magnitude of any opportunity costs associated with rice production will be small due to a relatively lower share of rice in total farm income. Differences in rice production systems, the level of income diversification, and the nature of drought in these latter two regions are thus the major factors determining the magnitude of economic losses.

### 1.5 Institutional responses to drought

There are a number of similarities in the public-sector responses to drought in all three regions. Institutional mechanisms have been set up to provide long-term drought-proofing as well as relief during drought years. Activities implemented for long-term drought-proofing have mainly centered on water resource development. These include major and minor irrigation schemes, farm ponds, and the overall development of watersheds for improving water retention and its effective use. During the 1960s and 1970s, large-scale irrigation schemes were developed to increase overall farm productivity by using the potential created by the Green Revolution. Protection from drought was not the primary reason for such investments. Over time, the emphasis shifted toward developing small and minor irrigation schemes, farm ponds, and watershed-based approaches. This change in approach is due partly to the high cost of large-scale irrigation development and the increasing realization that drought-prone areas require localized efforts that use local resources for effective protection from drought. Accordingly, small-scale irrigation and watershed development is a major response in eastern India, farm ponds are being promoted in northeast Thailand, and local water resources are being increasingly used in southern China.

Although water resource development is seen as a part of the broader rural development policy, a major response to drought has been the provision of relief. This is especially the case in eastern India, where the livelihoods of millions of poor people are affected by drought. The provision of food, agricultural inputs, and credit to the affected population has been a major component of drought mitigation policy in India generally. The provision of such assistance is needed to prevent hunger and starvation. However, it is now widely accepted that the provision of relief follows a "fire-fighting" approach of dealing with the immediate problem. Although food-for-work programs are meant to contribute toward long-term drought-proofing through asset building, the success on this score has been limited because of several design limitations, implementation difficulties, and their limited coverage resulting from budgetary constraints. Considerable opportunities exist for improving the effectiveness of drought relief through better targeting, active involvement of local-level agencies, quicker response time, continuation of activities after the drought is over, and the integration of interventions with overall agricultural development programs. These opportunities were discussed in detail in Chapter 4 in the context of eastern India.

In the case of southwestern China and northeast Thailand, relief is provided mainly in the form of subsidized agricultural inputs and construction/rehabilitation of irrigation schemes rather than the provision of food. Community-level decision making in the allocation and use of communally owned water resources has played an important role in generating quick responses to drought. The social and political system of China has empowered local communities to reallocate land and water resources for community benefits. Such community-level involvement is relatively weak in the other two regions. Given the higher income level and a relatively low share of agriculture in national income, dealing with a scarcity of water for industrial and domestic uses rather than for agriculture during drought years often dominates policy debates in Thailand.

## 2. Recommendations

### 2.1 Agricultural research

Improved rice technologies that help reduce losses to drought can play an important role in long-term drought mitigation. Important scientific progress is being made in understanding the physiological mechanisms that impart tolerance of drought (Blum 2005, Boyer 2005, Lafitte 2005). Similarly, progress is being made in developing drought-tolerant rice germplasm through conventional breeding and the use of molecular tools (Bennett 1995, Atlin et al 2005, Serraj 2005). The probability of success in developing rice germplasm that is tolerant of drought is likely to be substantially higher now than what it was 10 years ago. Complementary crop management research to manipulate crop establishment, fertilization and general crop care for avoiding drought stress, better use of available soil moisture, and enhancing the plant's ability to recover rapidly from drought can similarly help reduce losses.

Despite the potential role of improved technologies in drought mitigation, the level of agricultural research in developing countries is generally low. While industrialized countries invest about 2.6% of their agricultural GDP in research, the research intensity (or the ratio of research expenditure to agricultural GDP) for developing countries has been estimated to be around 0.62% (Pal and Byerlee 2003). For China and India, research intensities are only 0.43% and 0.29%, respectively. Clearly, agricultural research in the developing countries of Asia remains underinvested. The total agricultural research investment in India in 1998-99 was about US$430 million (Pal and Byerlee 2003). The economic losses from drought alone as estimated in this study by considering just rainfed rice-growing areas are close to this figure.

The allocation of research resources to rainfed areas and specifically to address abiotic constraints such as drought and submergence is even lower relative to the size of losses resulting from these constraints. A recent study from India illustrates the case in point. It has been found that the allocation of rice research resources to rainfed areas in India is disproportionately small relative to the potential contribution of these areas in making efficiency and equity impacts (Pandey and Pal 2007). The share of even this limited amount of resources targeted to address abiotic constraints such as drought and submergence is less than 10%.

It has been established that the marginal productivity of research resources may now be higher in rainfed environments than in irrigated environments and that agricultural research in unfavorable (rainfed) environments can generate a substantial poverty impact (Fan et al 2003). There is a strong justification for increasing research intensity in agriculture and allocating a larger proportionate share to rainfed areas to address drought and submergence, which are the dominant constraints to productivity growth.

## 2.2 Technology design considerations

Several design features need to be considered when developing improved technologies for effective drought mitigation. An important design criterion is that the technologies should improve flexibility in the decision regarding crop choices, the timing and method of crop establishment, and the timing and quantity of various inputs to be used. Flexibility in agricultural technologies permits farmers not only to reduce the chances of low income but also to adaptively capture income-increasing opportunities when they do arise. Technologies that lock farmers into a fixed set of practices and timetables do not permit effective management of risk in agriculture. In fact, the empirical analyses presented in this report indicate that farmers do not seem to have much flexibility in making management adjustments in rice cropping in relation to drought. Other than delaying crop establishment if rains are late, replanting and resowing when suitable opportunities arise, and some reduction in fertilizer use, farmers mostly follow a standard set of practices irrespective of the occurrence of drought. The timing of drought (mostly late rather than early) and the lack of suitable technological options have probably limited flexibility in making tactical adjustments in crop management practices to reduce losses. Examples of technologies that provide greater flexibility are varieties that are not adversely affected by delayed transplanting caused by early-season drought, varieties that perform equally well under both direct seeding and transplanting, and crop management practices that can be implemented over a wider time window.

Losses in agricultural production and income are an important factor that contributes to increases in poverty during drought years, as documented in this study. Technologies that reduce yield losses during drought years can avoid such adverse impacts on poverty even if there may be some associated trade-offs in yield during favorable years. Hence, in terms of poverty impact, higher priority should be accorded to research focused on lopping off the lower tail of the yield distribution than for raising the average yield by improving performance during normal years, if there are trade-offs involved in achieving both simultaneously.

The results presented earlier also indicate that late-season drought is more frequent and tends to have more serious economic consequences for poor farmers than early-season drought. In addition to having to deal with the consequences of low or no harvest, farmers also lose their investments in seed, fertilizer, and labor if the crop is damaged by late-season drought. Although early-season drought may prevent planting completely, farmers can switch early to other coping strategies such as wage labor and migration to reduce income losses in such years. Thus, the poverty impact of technology is likely to be higher if research focuses on late-season drought if tolerance of early- and late-season drought cannot be achieved simultaneously.

In rainfed areas, the land endowment of farmers typically consists of fields across the toposequence that have different hydrological conditions. Fields in the upper part of the toposequence are typically more drought-prone than those in the lower part. Farmers use such a hydrologically diversified portfolio of land by growing different varieties of rice that match field hydrological features. In addition, farmers grow a range of varieties for other reasons such as staggering of labor demand, grain quality, taste, and suitability to various uses. Breeding programs that produce a wider choice of plant materials with different characteristics and varying responses to drought that correspond with field hydrological features can play an important role in effective protection from drought.

Crop diversification is an important drought-coping mechanism of farmers. Rice technologies that promote and do not constrain such diversification are thus needed. In rainfed areas, shorter-duration rice varieties can facilitate planting of a second crop using residual moisture. Similarly, rice technologies that increase not just yield but also labor productivity will facilitate crop and income diversification. Higher labor productivity in rice production will relax the labor constraint to diversification that may exist. Examples of such technologies are selective mechanization, direct seeding, and chemical weed control.

## 2.3 Water resource development

Development of water resources is an important area that is emphasized in all three countries for providing protection against drought. Opportunities for large-scale development of irrigation schemes that were the hallmark of the Green Revolution are limited now due to high costs and increasing environmental concerns (FAO 1997, Rosegrant et al 2002, Gulati et al 2005). However, there are still substantial opportunities to provide some protection from drought through small and minor irrigation schemes and through land-use approaches that generally enhance soil moisture and water retention. In the Indo-Gangetic Plains, supplemental irrigation from tubewells, minor lift irrigation schemes, dug-wells, and community ponds are widely used (Shah 1993, 2001a, Moench 2002). In China and Thailand, the use of farm and community ponds is also common. These small private or community-owned schemes tend to be low-cost and sufficiently responsive to local needs. Similarly, watershed-based approaches that are implemented in drought-prone areas of India provide opportunities for achieving long-term drought proofing by improving overall moisture retention within watersheds (Rao 2000). Public-sector support for further development, maintenance, and rehabilitation of these schemes could make them more effective in mitigating drought. Public-sector involvement, however, should be limited to the provision of technical assistance, while the actual management of these small scale-schemes is better left to local communities (Turton 2000, Shah 2001b, Kerr et al 2002).

## 2.4 Drought characterization, analysis, and mapping

Although drought occurs regularly and governments respond by providing relief and other forms of assistance to the affected communities, detailed scientific characterization of drought, analysis of its impact, and mapping are not being adequately conducted at both the local (province, district, state) and national levels. Such analyses and mapping are critically important for developing and implementing suitable short- and long-term strategies for drought mitigation. For example, in the study areas in China and Thailand, local authorities were not able to provide much information regarding drought. Drought research is much more advanced in India but it focuses mainly on the arid and semiarid zones. No major agencies are conducting in-depth analysis of the nature and impact of drought in the subhumid zone. Establishment of such agencies and linking them up with organizations involved in drought management at various levels would improve overall drought management.

### 2.5 Drought relief and long-term drought mitigation

In all three countries studied, a major response to drought has been to provide relief to the affected population. India has the most elaborate institutional setup for providing drought relief, which mainly takes the form of employment generation through public works. Affected people are also provided with some inputs and credit. While the provision of relief is essential to reduce the incidence of hunger and starvation, the major problems with the relief programs are slow response, poor targeting of beneficiaries, and limited coverage due to budgetary constraints. A "fire-fighting" approach that underlies the provision of drought relief cannot provide long-term drought proofing despite the large amount spent during drought years (Rao 2000, Hirway 2001). It is important that the provision of relief during drought years be complemented by a long-term strategy of investing in soil and water conservation and use, policy support, and infrastructure development to promote crop and income diversification in drought-prone areas, and encouraging community participation in managing and augmenting local water resources. Important progress is being made through watershed development programs in various parts of India, but these programs are not sufficiently integrated with overall agricultural development activities, thus diluting their potential impact (Rao 2000). In addition, a decentralized institutional setup that promotes greater participation and decision making by local-level agencies is needed to improve the overall effectiveness of relief programs, which mostly tend to be top-down in design.

### 2.6 Drought forecasting and preparedness

Scientific advances in meteorology and informatics have made it possible now to forecast drought with a reasonable degree of accuracy and reliability. Various indicators such as the Southern Oscillation Index (SOI) are now routinely used in several countries to make drought forecasts (Wilhite et al 2000, Hansen 2002, Zschau and Kueppers 2003, Meinke and Stone 2005). Suitable refinements and adaptations of these forecasting systems are needed to enhance drought preparedness at the national level as well as to assist farmers in making more efficient decisions regarding choice of crops and cropping practices (Abedullah and Pandey 1998). Currently, rice farmers in Asia do not generally receive much advance warning of impending drought. Even when general forecasts regarding the likelihood of drought are made, these are seldom translated adequately into a form that is useful for agricultural decision-making. Improvements in drought forecasting systems, the identification of efficient agricultural management practices to reduce the impact of drought, and provision of timely advice to farmers are activities that can help reduce the overall economic cost of drought and improve preparedness to deal with the inevitable consequences of drought.

### 2.7 Policies for promoting income diversification

Although technological interventions can be critical in some cases, they are not the only option for improving the management of drought. There is a whole gamut of policy interventions that can improve farmers' capacity to manage drought through more effective income- and consumption-smoothing mechanisms (Reardon et al 1992). Improvements in rural infrastructure and marketing that allow farmers to diversify their income sources can play an important role in reducing overall income risk. Investment in rural education can similarly help diversify income. In addition, such investments contribute directly to income growth that will further increase farmers' capacity to cope with various forms of agricultural risks. Widening and deepening of rural financial markets will also be a critical factor for reducing fluctuations in both income and consumption over time (Lanjouw and Lanjouw 2001, Barrett 2005, Haggblade et al 2006).

### 2.8 Crop insurance

Insurance provides a safety net to people through pooling of risk across economic agents by means of formal and informal mechanisms. Crop insurance is a potentially useful market-based instrument to protect farmers from weather-related risks.

Although the conventional forms of crop insurance are unlikely to be successful due to problems such as moral hazard and adverse selection (Hazell et al 1986), innovative approaches such as rainfall derivatives and international re-insurance of agricultural risks can provide promising opportunities (Walker and Ryan 1990, Gautam et al 1994, Skees et al 1999, Turvey 2001, WB 2003, Glauber 2004). However, these alternative schemes have not yet been adequately evaluated. There are important challenges in employing weather risk markets in developing countries (Varangis 2002, Skees et al 2001). More work is needed for developing and pilot testing new types of insurance products and schemes suited to the hundreds of millions of small farmers of Asia who grow rice primarily for subsistence.

## 3. Concluding remarks

Even in subhumid rice-growing areas of Asia, drought is clearly an important climatic factor that has large economic costs, in terms of both the actual economic losses during drought years and losses arising from opportunities for economic gains forgone. The provision of relief has been the main form of public response to drought. Although important in reducing the hunger and hardship of the affected people, the provision of relief alone is clearly inadequate and may even be an inefficient response for achieving longer-term drought mitigation. Given the clear linkage between drought and poverty as demonstrated in this study, it is critically important to include drought mitigation as an integral part of a rural development strategy. Policies that in general increase income growth and encourage income diversification also serve to protect farmers from the adverse consequences of risk, including that of drought.

The scientific progress made in understanding the physiology of drought and in developing biotechnology tools has opened up promising opportunities for making a significant impact on drought mitigation through improved technology. However, agricultural research in general remains grossly underinvested in the developing countries of Asia. This is a cause for concern, not only for drought mitigation, but for promoting overall agricultural development.

## References


Abedullah, Pandey S. 1998. Risk and the value of rainfall forecast for rainfed rice in the Philippines. Philipp. J. Crop Sci. 23(3):159-165.

Atlin GN, Lafitte HR, Tao D, Laza M, Amante M, Courtois B. 2005. Developing rice cultivars for high-fertility upland systems in the Asian tropics. Field Crops Res. 97(2006):43-52.

Barrett CB. 2005. Rural poverty dynamics: development policy implications. Agric. Econ. 32:45-60.

Bennett J. 1995. Biotechnology and the future of rice production. GeoJournal 35:335-337.

Blum A. 2005. Drought resistance, water-use efficiency, and yield potential—are they compatible, dissonant, or mutually exclusive? Aust. J. Agric. Res. 56:1159-1168.

Boyer JS. 2005. Plant reproduction undress stress. Invited speaker. INTERDROUGHT-II: coping with drought. The 2nd international conference on integrated approach to sustain and improve plant production under drought stress, Rome, Italy, 24-28 Sept. 2005. The University of Rome, Rome, Italy. On-line at www.plantstress.com.

Fan S, Chan-Kang C, Qian K, Krishnaiah K. 2003. National and international agricultural research and rural poverty: the case of rice in India and China. In: Mew TW, Brar DS, Peng S, Dawe D, Hardy B, editors. Rice science: innovations and impact for livelihood. Los Baños (Philippines): International Rice Research Institute. p 807-846.

FAO (Food and Agriculture Organization of the United Nations). 1997. Irrigation potential in Africa: a basin approach. Land and Water Development Division. Rome (Italy): FAO. On-line at www.fao.org/docrep/W4347E/W4347E00.htm.

Gautam G, Hazell P, Alderman H. 1994. Rural demand for drought insurance. Policy Research Working Paper 1383, Agriculture and Natural Resources Department and Policy Research Department. Washington, D.C. (USA): The World Bank.

Glauber JW. 2004. Crop insurance reconsidered. Am. J. Agric. Econ. 86:1179-1195.

Gulati A, Meinzen-Dick R, Raju KV. 2005. Institutional reforms in Indian irrigation. New Delhi (India): Sage Publications.

Gypmantasiri P, Limnirankul B, Muangsu C, editors. 2003. Integration of farmer participatory plant breeding for rainfed lowland rice improvement in north and northeast Thailand. I. Biophysical and socio-economic characterization of rainfed lowland rice production systems of the north and the northeast of Thailand. Ubon (Thailand): Ubon Ratchathani Rice Research Center.

Haggblade S, Hazell P, Reardon T. 2006. Transforming the rural non-farm economy. Baltimore, Md. (USA): Johns Hopkins University Press. (Forthcoming.)

Hansen JW. 2002. Realizing the potential benefits of climate prediction to agriculture: issues, approaches, challenges. Agric. Syst. 7:309-330.

Hazell P, Pomerada C, Valdes A. 1986. Crop insurance for agricultural development. Baltimore, Md. (USA): Johns Hopkins University Press.

Hirway I. 2001. Vicious circle of droughts and scarcity works: why not break it? Ind. J. Agric. Econ. 56(4):708-721.

Hossain M. 1996. Recent developments in the Asian rice economy: challenges for rice research. In: Evenson E, Herdt RW, Hossain M, editors. Rice research in Asia: progress and priorities. Wallingford (UK): CAB International. p 17-33.

INDIAAGRISTAT data. 2005. Database on Indian agriculture. Datanet India Pvt. Ltd., New Delhi, India. On-line at www.indiaagristat.com.

Kerr J, Pangare G, Pangare LP. 2002. Watershed development projects in India: an evaluation. Research Report 127. Washington, D.C. (USA): International Food Policy Research Institute.

Lafitte R. 2005. Whole plant responses, key processes, and adaptation to drought stress. Invited speaker. INTERDROUGHT-II: coping with drought. The 2nd international conference on integrated approach to sustain and improve plant production under drought stress; Rome, Italy, 24-28 Sept. 2005. The University of Rome "La Saienza", Rome, Italy. On-line at www.plantstress.com.

Lanjouw J, Lanjouw P. 2001. The rural non-farm sector: issues and evidence from developing countries. Agric. Econ. 26:1-23.

Meinke H, Stone RC. 2005. Seasonal and inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations. Climatic Change 70(1-2):221-253.

Moench M. 2002. Groundwater and poverty: exploring the connections. In: Llamas R, Custodio E, editors. Intensive use of groundwater challenges and opportunities. Abingdon, UK.

NBS (National Bureau of Statistics of China). 2005. China statistical yearbook 2004. National Bureau of Statistics. Beijing (China): China Statistics Press. On-line at www.stats.gov.cn/english.

NCAP-IRRI eastern India rice database. 2002. Time-series area, production, and yield of rice and monthly rainfall database. Los Baños (Philippines): International Rice Research Institute.

OAE (Office of Agricultural Economics). 2004. Agricultural statistics of Thailand crop year 2003/04. OAE, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Pal S, Byerlee D. 2003. The funding and organization of agricultural research in India: evolution and emerging policy issues. National Center for Agricultural Economics and Policy Research (NCAP) Policy Paper 16. New Delhi (India): Indian Council for Agricultural Research (ICAR).

Pandey S, Pal S. 2007. Are less-favored environments over-invested? The case of rice research in India. Food Policy (forthcoming).

Rao CHH. 2000. Watershed development in India: recent experiences and emerging issues. Econ. Politic. Weekly, 4 November 2004.

Reardon T, Delagado C, Matlon P. 1992. Determinants and effects of income diversification amongst farm households in Burkina Faso. J. Dev. Studies 28(2):264-296.

Rosegrant MW, Cai X, Cline S. 2002. World water and food to 2025: dealing with scarcity. International Food Policy Research Institute (IFPRI), Washington, D.C. (USA) and International Water Management Institute (IWMI), Colombo, Sri Lanka.

Serraj R. 2005. Genetic and management options to enhance drought resistance and water use efficiency in dryland agriculture. Selected talk. INTERDROUGHT-II: coping with drought. The 2nd international conference on integrated approach to sustain and improve plant production under drought stress; Rome, Italy, 24-28 Sept. 2005. The University of Rome "La Saienza", Rome, Italy. On-line at www.plantstress.com.

Shah T. 1993. Groundwater markets and irrigation development: political economy and practical policy. Mumbai (India): Oxford University Press.

Shah T. 2001a. Wells and welfare in the Ganga basin: public policy and private initiative in eastern Uttar Pradesh, India. Research Report 54. Colombo (Sri-Lanka): International Water Management Institute.

Shah A. 2001b. Who benefits from participatory watershed development? Lessons from Gujarat, India. Gatekeeper Series No. 97. London (UK): International Institute for Environment and Development.

Skees J, Hazell P, Miranda M. 1999. New approaches to crop insurance in developing countries. Environment and Production Technology Division (EPTD) Discussion Paper 55. Washington, D.C. (USA): International Food Policy Research Institute.

Skees JR, Gober S, Varangis P, Lester R, Kalavakonda V. 2001. Developing rainfall-based index insurance in Morocco. World Bank Policy Research Working Paper 2577. Washington, D.C. (USA): The World Bank.

Turton C. 2000. Enhancing livelihoods through participatory watershed development in India. The Sustainable Livelihoods Working Paper Series 131. London (UK): Overseas Development Institute (ODI).

Turvey CG. 2001. Weather derivatives for specific event risks in agriculture. Rev. Agric. Econ. 23:333-351.

Varangis P. 2002. Innovative approach to cope with weather risk in developing countries. The Climate Report 2 (2). Climate Risk Solutions, Inc.

Walker TS, Ryan JG. 1990. Village and household economies in India's semi-arid tropics. London (UK): Johns Hopkins University Press.

WB (World Bank). 2003. Karnataka crop insurance study. South Asia Region, Washington, D.C. (USA): The World Bank.

Widawsky DA, O'Toole JC. 1990. Prioritizing the rice biotechnology research agenda for Eastern India. The Rockefeller Foundation, New York, USA.

Wilhite DA, Shivakumar MKV, Wood DA. 2000. Early warning systems for drought preparedness and drought management. Proceedings of an expert Group Meeting in Lisbon, Portugal, 5-7 Sept. World Meteorological Organization, Geneva, Switzerland.

Zschau J, Kueppers AN, editors. 2003. Early warning systems for natural disaster reduction. Berlin (Germany): The Springer Publishing Company.

## Notes

*Authors' addresses:* S. Pandey, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines; H. Bhandari, Social Sciences Division, International Rice Research Institute, Los Baños, Philippines, currently with Japan International Research Center for Agricultural Sciences, 1-1, Ohwashi, Tsukuba, Ibaraki 305-8686, Japan.