Drought, coping mechanisms and poverty

Insights from rainfed rice farming in Asia

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Insights from rainfed rice farming in Asia

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This paper summarizes the main results and implications of a research study analysing the economic costs of drought in Asia and rice farmers' coping mechanisms. The research was carried out by the International Rice Research Institute (IRRI), the Philippines, with financial support from the Rockefeller Foundation. The paper draws heavily on the study, *Economic costs of drought and rice farmers' coping mechanisms*, published by IRRI in 2007. We would like to thank our collaborators from China, India and Thailand, and their staff who were involved in the study.

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Foreword

Drought represents a major constraint on food production in the Asia and the Pacific region. Some 23 million hectares are drought-prone, representing a fifth of the total rice area of the region. A recent report of the Intergovernmental Panel on Climate Change highlights the increasing frequency and intensity of droughts in many parts of Asia. These increases are attributed mainly to a rise in temperature, in particular during the summer and normally drier months and during El Niño Southern Oscillation (ENSO) events. Drought is affecting large tracts of the main rice-producing areas of Asia. In China, for example, the increase in area affected has exceeded 6.7 million hectares since 2000. In South Asia nearly half the droughts are associated with El Niño, and consecutive droughts in 1999 and 2000 in Pakistan and north-western India led to sharp declines in water tables and crop failures. In South-East Asia, as well, droughts are normally associated with ENSO years.

Past studies of drought have focused mainly on arid and semi-arid regions. Although subhumid regions of Asia also suffer from frequent droughts, researchers have not studied the problem and its impact on farmer livelihoods in these areas. The economic costs of drought here can be enormous. For example, the total economic cost of drought in eastern India is estimated to be as high as 11 per cent of total agricultural GDP.

The present paper summarizes the findings of a research study that sought to fill the knowledge gap regarding the effects of drought in subhumid rice-producing areas. In addition to estimating the economic costs of drought in major rice-producing countries of Asia, it documented farmers' risk-coping mechanisms. Farmers in these countries use a variety of coping strategies to deal with the consequences of drought, including careful choice of cropping patterns, rice varieties, planting methods and crop management practices. The study also identified possible technological and policy interventions for effective drought management.

The International Rice Research Institute, which undertook the research, is collaborating with IFAD on a programme for technology development for rice in upland areas of Asia. We believe that the findings and recommendations will be of interest to policy makers, development practitioners, donors, academics and civil society.

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Executive summary

Drought is a recurrent phenomenon and an important constraint on agricultural production in humid and subhumid rice-growing areas of Asia. At least 23 million hectares in Asia (20 per cent of the total rice area) are subject to droughts of varying intensities, which is one of the major factors contributing to low and unstable production. The economic costs of drought include not only the rice production loss, but also the loss in production of post-rice crops grown on residual soil moisture. Production practices designed to reduce losses from drought cause additional economic and social costs, as do the depletion of productive assets due to distress sale during drought years and the consequent long-term decline in productive capacity. Drought thus causes enormous socio-economic and environmental impact in terms of food and livelihood insecurity, increasing poverty and vulnerability, and negative environmental consequences. It is believed that the frequency and severity of drought are increasing due to climate change. As a result, the socio-economic impact is expected to rise in the future.

Farmers make various adjustments in their production, consumption and livelihood practices and adopt conservative measures to reduce the negative impact of drought. The production adjustments and conservative measures reduce direct production losses. The consumption and livelihood adjustments, on the other hand, help in smoothing consumption costs and income. Nevertheless, these adjustments, themselves, entail some economic costs in terms of lost opportunities for income gains in good years. More importantly, the appropriateness and effectiveness of adjustments depend on the information, knowledge and skills of individual farmers and communities.

An understanding of the socio-economic impact of drought and of farmers' coping mechanisms is essential in designing technological and policy interventions for more-effective drought mitigation and relief. Nevertheless, knowledge of drought is very limited in terms of its characteristics, its impact on farmer livelihoods, farmers' coping strategies and the welfare implications in subhumid regions of Asia.

This paper synthesizes the major findings of a recent, cross-country comparative research study of the economic costs of drought in Asia and farmers' coping mechanisms. The countries and regions included in the study were southern China, eastern India and north-eastern Thailand. These three regions capture a range of climatic conditions, levels of economic development, rice yields and institutional set-ups. Published secondary data and farm household survey data were used in the study. Over 30 years of time-series, published secondary data on rice and non-rice crop production and rainfall were used to characterize drought and to estimate economic losses due to drought at the aggregate level. Farm survey data were used to estimate the household-level impact of drought and to analyse farmers' coping mechanisms. Various statistical and econometric methods were used to analyse the collected data.

The probability of drought was found to vary from 10 to 40 per cent in subhumid regions of Asia, despite an annual average rainfall in the range of 1,000-1,500 mm. The probability of late season drought was generally higher than that in early season. At the aggregate level, the estimated annual average loss in crop production due to drought in eastern India was 7 per cent of the average value of agricultural output (US$162 million for the three states combined), although production loss during drought years was estimated at 30-40 per cent. Both yield loss and area loss contributed to production losses. However, the loss in yield accounted for the major share. In southern China and north-eastern Thailand, production losses were much smaller, at less than 1.5 per cent of the average value of agricultural output.

At the micro level, analysis of farm household survey data from the three countries indicated that drought-affected households suffered rice production losses of from 44 to 71 per cent. Even in southern China and north-eastern Thailand, where aggregate rice production losses were small, losses for households affected by drought were substantial. Across the toposequence, production losses were found to be substantially higher in upper fields (or uplands), which typically have lower moisture-holding capacity, than in midland or lowland fields.

Analysis of data from eastern India showed that the drop in agricultural income during a drought year was in the range of 40-80 per cent of normal-year income. Farmers attempted to compensate this loss by seeking additional employment in the non-farm sector. This additional income, however, was clearly inadequate to compensate the loss in agricultural income, thus resulting in a drop in total income of 25-60 per cent. Farmers relied on three main mechanisms to recoup this income loss: selling productive assets, using savings and borrowing. These adjustments helped recover only 6-13 per cent of the total loss in income. Households still ended up with 20-50 per cent lower income than in a normal year, despite all the adjustments. Thus the various coping mechanisms that farmers deployed were inadequate to prevent a shortfall in income.

Consequently, the incidence and severity of poverty increased substantially during drought years. Almost 13 million additional people 'fell back' into poverty in three states of eastern India due to drought. This translated into an increase in rural poverty in the three states combined of 19 percentage points and at the national level of 1.6 percentage points. In addition, those people who were poor even during a normal year were pushed deeper into poverty. Households with small farm sizes, with proportionately more area of drought-prone upland fields, and with a smaller number of working-age members were found to be more vulnerable to such adverse income consequences.

Farmers employ different combinations of ex ante and ex post drought coping strategies to minimize the impact of drought. Ex ante coping strategies include careful choice of rice varieties, planting date, crop establishment methods, and weeding and fertilization practices to minimize the effects of drought. In addition, farmers also make temporal adjustments in cropping patterns based on the timing of drought occurrence. Overall, farmers do not seem to have much flexibility in making management adjustments in rice crop 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 probably have limited farmers' flexibility in making tactical adjustments in crop management practices to reduce losses. Direct seeding rather than transplanting, using mixed rather than monocropping, and saving seeds and seedlings are other strategies.

Farm households also employ a wide range of ex post drought coping strategies, which include dependence on wage income; increased borrowing; liquidation of productive assets; higher rate of seasonal out-migration; increased use of social networks; increased dependence on forests for food, livestock pasturing and income; forced reduction of expenditures on items such as clothing, social functions, food, medical treatment and children's education; adjustments in food balance; and reliance on public relief. Despite these adjustments, most farmers in India were unable to maintain their normal-year level of consumption. As a result, households were forced to reduce the number of meals per day and the quantity consumed per meal. In this context, women and children bore the burden of drought disproportionately. Other strategies are distress selling of livestock and borrowing by mortgaging fixed and movable assets.

The household-level impact of drought was found to be smaller in China and Thailand than in India. The relative importance of coping strategies varied across regions. In India, farmers relied mainly on migration, sale of draft animals and borrowing for income-smoothing. In China and Thailand, however, farmers relied mainly on diversification of farm and non-farm income. In-crop adjustments in rice production and crop substitution during drought years did not play significant roles in any of the three regions. A more commercialized agriculture and a greater diversification of farm incomes were factors contributing to the smaller impact of drought in China and Thailand relative to India.

Institutional mechanisms that emphasize both long-term 'drought-proofing' and short-term drought relief have been set up in all three countries. The long-term mitigation activities are mainly centred on water resource development, including irrigation schemes, farm ponds and watershed development. Nevertheless, provision of relief has been the main form of public policy response to drought management. Despite considerable expenditure on drought mitigation and relief in the past, overall economic and social costs of drought remain high.

The enormous economic and social costs of drought warrant more emphasis on drought mitigation strategies such as technological improvements and policy interventions. Technological improvements include the development of rice varieties that can escape or tolerate drought. Scientific progress in understanding the physiology of drought and in the development of biotechnology tools offers the promise of significant impact in drought mitigation. Promotion of appropriate crop establishment methods, improving agronomic practices that augment soil moisture and development of appropriate post-rainy-season cropping systems are other technological options for drought mitigation. However, agricultural research in general remains grossly underinvested in developing countries of Asia. This is cause for concern, not only for drought mitigation, but for promoting overall agricultural development. Other relevant factors include national and local institutional capacity for research and programme implementation.

Increased moisture availability to crops through water conservation and harvesting and watershed development is an important strategy for drought mitigation. Although the opportunities for large-scale development of irrigation facilities in drought-prone areas are limited, better management of local rainfall through water harvesting and moisture conservation measures can accomplish much.

In addition to technological interventions, a range of policy interventions can improve farmers' capacity to manage drought through more effective income- and consumption-smoothing mechanisms. Improvements in rural infrastructure, marketing and extension that allow farmers to diversify their income sources can play an important role in reducing overall income risk. Investment in rural education can increase return to labour as well as help diversify income. Widening and deepening of rural financial markets will also be a critical factor in smoothing income and consumption and minimizing post-drought consequences. Improvements in drought forecasting, efficient provision of this information to farmers, and rainfall-based crop insurance are other important interventions. Public policy response to drought must focus on long-term mitigation as opposed to short-term relief. The effectiveness of relief programmes can be improved through better targeting, public participation, timely response and the integration of interventions into overall agricultural development programmes. These institutional and policy interventions can be designed to complement technologies for maximum impact. Although some progress has been made during the past decade, much remains to be done.

Introduction

Climate-related natural disasters such as drought, flooding, storms and tropical cyclones 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. As a result, climatic variations significantly impact the livelihood of millions – and particularly poor and vulnerable people. While 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 a staple crop of Asia. Although the production of rice has increased over time in the wake of green revolution and other technological advancements, major shortfalls caused by climatic aberrations such as drought and flooding are frequent. Drought is one of the major constraints on rice production. At least 23 million hectares (ha) of rice (20 per cent of total rice area) are drought-prone (Table 1). India accounts for the largest share (59 per cent) of the total drought-prone rice area in Asia. Most of these areas are rainfed.

The economic costs of drought can be enormous. For example, it has historically been associated with food shortages of varying intensities, including those that have resulted in major famines in various parts of Asia and Africa. In India, major droughts in 1918, 1957/58, and 1965 resulted in famines in the twentieth century (FAO 2001). The 1987 drought affected almost 60 per cent of the total cropped area and 285 million people across India (Sinha 1999). Similarly, the average annual drought-affected area

Table 1
Drought-prone rice area in Asia (million ha)

Country	Rice area[a]		Drought-prone	
	UR	RL	UR[b]	RL[c]
India	6.3	16	6.3	7.30
Bangladesh	0.9	6	0.9	0.80
Sri Lanka	0.06	0.2	-	na
Nepal	0.1	1.0	0.1	0.27
Myanmar	0.3	2.5	0.3	0.28
Thailand	0.05	8	-	3.1
Laos	0.2	0.4	0.2	0.09
Cambodia	-	1.7	-	0.20
Viet Nam	0.5	3	0.5	0.30
Indonesia	1.1	4	1.1	0.14
China	0.6	2	0.6	0.50
Philippines	0.07	1.2	-	0.24
Total	10	46	10	13

a Source: IRRI (1997).
b Assuming all upland rice (UR) area as drought-prone.
c Source: Mackill, Coffman and Garrity (1996). Rainfed lowland (RL) rice area is classified as drought-prone and drought-and-submergence-prone. The table figures provide lower bound estimates as the drought-prone-and-submergence-prone area is excluded.

in China over the period 1978-2003 is estimated at 14 million ha, and the direct economic cost of drought is estimated at 0.5-3.3 per cent of agriculture-sector GDP. In 2004, a severe drought hit many countries in South-east Asia and caused the shrivelling of crops on millions of hectares, costing millions of dollars, shortages of water for drinking and irrigation, and the suffering of millions of people. In Thailand, the drought of 2004 alone is estimated to have affected 2 million ha of cropped area and over 8 million people (Bank of Thailand 2005, Asia Times 2005).

The effect of drought on human societies can be multidimensional. Its effect in terms of production losses and consequent human misery is well-publicized in years of crop failure. However, losses due to drought of milder intensity, although not as visible, can also be substantial. Production loss, which is often used as a measure of the cost of drought, is only a part (often a small 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. As a result of market failures, farmers attempt to 'self-insure' by making costly adjustments in their production practices and adopting conservative measures to reduce the negative impact in drought years. Although these adjustments reduce direct production losses, they entail some economic costs in terms of lost opportunities for income gains in 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 to other sectors. A decrease in agricultural income will reduce the demand for products of the agro-processing industries that cater to local markets. This will lead to a reduction in income and employment in the sector. Similarly, the income of rural households engaged in providing agricultural inputs will also decrease. This reduction in household income will set off secondary effects. By the time these effects have 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 also result in a decrease in consumption by poor people, whose consumption levels are already low. Farmers may attempt to 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 of drought is based on arid and semi-arid regions (Jodha 1978; Campbell 1999; Shivakumar and Kerbart 2004; Rathore 2004). However, despite reasonably high rainfall, drought occurs frequently in the subhumid regions of Asia (Pandey, Bhandari and Hardy 2007). Rainfed and partially irrigated rice-growing areas in subhumid tropics have low agricultural productivity and are major 'poverty hotspots'. The nature and frequency of drought in these regions, its impact on farmers' livelihoods and drought coping strategies, and the welfare implications of drought have not been adequately studied. Analyses of drought characteristics and impact and of household coping mechanisms are important in understanding the nature of risk and vulnerability associated with drought and in formulating interventions for effective drought mitigation. The present paper seeks to: provide estimates of the economic costs of drought in the major rice-growing countries of Asia; document farmers' coping mechanisms in drought-prone rice areas of Asia; and identify possible technological and policy interventions for effective drought management.

The paper synthesizes the findings and recommendations of recent research involving a cross-country comparative study of the impact of drought and farmers' coping mechanisms (Pandey, Bhandari and Hardy 2007). The countries included in the study were China, India and Thailand. These countries vary in climatic conditions, level of economic development, rice yield, and institutional and policy contexts of rice farming. The specific regions selected for the study were southern China, eastern India and north-eastern Thailand. In southern China, the provinces included were Hubei, Guangxi and Zhejiang. Eastern India was represented by the states of Chattisgarh, Jharkhand and Orissa. All provinces of north-eastern Thailand were included. General characteristics of rice production and economic indicators of the countries/regions in the study are summarized in Table 2. Comparative analyses of the impact of drought and responses from these varying conditions can provide better insights than can studies of individual countries conducted separately.

Table 2
General characteristics of the three countries in the study

Characteristics	China	India	Thailand
Per capita gross national income (US$), 2006	2 000	820	3 050
Population below national poverty line (%), latest	10	25	10
Population of study area (million)[a]	155	88	21
Average land holding (ha household^{-1})	1.48	1.4	2.3
Share of agriculture in total GDP (%), 2007	12	17	11
Share of agriculture in total employment (%), 2007	43	60	49
Irrigated rice area (% of total rice area)	93	50	20
Rice yield (tons/ha^{-1})[b]	6.3	3.1	2.9
CV of rice production (study area)[c]	5	18	10
Share of world rice production (%)[d]	29	21	5
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 the study.
b Rice yield was estimated using 2004-2006 data, for the whole country.
c Coefficient of variations (CV) was estimated using 1970-2003 data for the provinces/states included in the study.
d Share of world rice production was estimated using 2004-2006 data.
Sources: FAOSTAT (2008), World Bank (2008), CIA (2008) and IRRI (2005).

I. Drought: Definition and impact

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 semi-arid regions and frequently occurs in humid regions as well. The common belief that drought occurs only in low rainfall areas is not true at all. 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 substantially below what has been established as a 'normal' value for the area concerned, leading to adverse consequences for human welfare. Although drought is a climatically induced phenomenon, its impact depends on social and economic contexts as well. Considering its complex nature and wide variation across time and space, it is somewhat impractical to develop a universally applicable definition of drought. The definition also depends on the disciplinary perspective. Three such definitions based on meteorological, hydrological and agricultural perspectives are available (Wilhite and Glantz 1985).

This paper mainly utilizes the meteorological definition of drought. It is defined as a situation in which actual rainfall is significantly below the long-term average (LTA) for the area. Drought is considered to have occurred when rainfall during the monsoon season is less than 80 per cent of the LTA. This is obviously a simplified definition, which does not take into account factors other than the total seasonal rainfall. In addition to total rainfall, crop production depends critically on the seasonal distribution of rainfall over the crop growth duration.

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

Crop response to moisture deficit depends on the timing and intensity of drought. Most annual crops are highly sensitive to moisture deficit during the flowering and grain-formation stages of growth. Even short periods of drought during these critical stages can cause substantial production losses. In the case of rice, early season drought (i.e. 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, aggregate impact of drought also depends on the spatial covariance. A spatially covariate drought (i.e. a wide-spread drought covering a large area) will have a much larger impact than that of a localized one. The 2002 drought in India, for example, was widespread and affected more than half the country's geographical area.

Drought differs from other natural disasters in three main aspects (Wilhite 2000). First, it 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, common definition of drought adds to confusion about its occurrence and severity. Third, damage due to drought does not normally involve damage to infrastructure (unlike flooding, earthquakes, etc.). Due to its less obvious damage, it 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 and reach far beyond the geographical boundaries.

II. Farmers' drought coping strategies[1]

Coping strategies can be classified into ex ante and ex post, according to whether they help reduce risk or reduce the impact of risk after the production shortfall has occurred. Due to the 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 the fluctuations in income and are also referred to as income-smoothing strategies. However, they can 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 one's 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 non-farm activities.

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 according to the climatic conditions. While postponing agricultural decisions until uncertainties are reduced can help lower the 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 shortfall in consumption when income drops below that needed to maintain 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 fluctuates. These include migration, consumption loans, asset liquidation and charity. 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 coping mechanisms. Many ex ante strategies such as crop diversification and low use of inputs are of this nature. Others are employed only under certain risky situations and are easier to identify as responses to risk.

1 A detailed discussion of farmers' drought coping mechanisms is available in Pandey, Bhandari and Hardy (2007).

III. Economic costs of coping mechanisms

The opportunity costs associated with deployment of various coping mechanisms can be great. The climatic uncertainties often compel farmers, particularly risk-averse ones, to employ conservative risk management strategies that reduce the negative impact in poor years, but often at the expense of reducing average productivity and profitability (Anderson 2001, Hansen 2002). For example, by growing drought-hardy, but low-yielding traditional rice varieties, farmers may be able to minimize the drought risk but will end up sacrificing a potentially higher income in normal years. In addition, poor farmers in high drought-risk environments are reluctant to invest in seed and fertilizer technologies that could increase profitability in normal years, but lead to loss of capital investment in poor years.

Anderson (1995) estimated the economic cost of risk aversion to be about 10 per cent of average income. Similarly, Antle (1987) showed a 14 per cent reduction in expected net profit due to inefficiency in labour allocation. Although the inefficiency cost may appear small in percentage terms, this involves a substantial reduction in the average income of poor farmers on or barely above the poverty line.

In addition to these opportunity costs, poor households compelled to sell their productive assets such as bullocks and farm implements will suffer future productivity losses, as it takes them several years to reacquire those assets. Reductions in medical expenses and children's education will impact future household income, and may linger on to the next generation. The loss of income and assets can convert transient poverty into chronic poverty, making the possibility of escape more remote (Morduch 1994).

IV. Analytical approach

The study conducted two types of analysis. The first relates to the characterization of drought and estimation of the aggregate value of production loss. The second involves an assessment of drought impact at the farm household level and an investigation of coping mechanisms.

Aggregate-level analysis

Estimation of aggregate production loss involves analysis of published temporal data on rainfall and crop production at the province (or state) and county (or district) level (Table 3). The same data are used to estimate aggregate economic losses from drought by correlating drought events with crop production. Actual crop production over a span of years with and without drought is used in this study, as opposed to the usual practice of estimating production loss using farmers' or researchers' subjective estimates of yield losses and probability of drought (Widawsky and O'Toole 1990, Hossain 1996, Gypmantasiri, Limnirankul and Muangsu 2003).

Drought was defined in terms of deficiency of actual rainfall relative to LTA rainfall. Following a similar approach used by the Indian Meteorological Department and other literature sources (Pandey et al. 2000, DAC 2003), drought is considered to occur in a particular year if the annual rainfall is less than 80 per cent of the LTA. The main focus of this study was rice, which is grown mainly during the monsoon season. Hence, in

Table 3
Description of secondary data used in the study, three countries

Country	Province/ state/zone[a]	Number of selected county/district/province[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 were used for this study.
b Geographical size of provinces in north-eastern 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. The 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 is available at the aggregate level only. Thus data up to 2003 were used in the aggregate-level analysis in some cases.

the context of the study, drought is considered to have occurred if rainfall during the monsoon season is less than 80 per cent 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. Characterization of the timing, intensity, frequency and spatial pattern of drought is formulated using long-term, monthly rainfall data at the province (or state) and county (or district) level.

The rice-growing season is divided into three parts to assess the incidence of drought during diverse periods and its impact on production. These are the early, medium and late seasons. Frequency of drought during each season is estimated as the number of years in which rainfall is below 80 per cent of the LTA for that particular season.

In addition to this meteorological analysis, drought declarations made by local and national governments can also be used to identify 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 a drought year for relief purposes when the impact of drought is severe. Both indicators of drought (rainfall-based and government-declared) are used in estimating the probability of drought.

A discrete drought dummy variable is specified in a linear trend equation on production (Q). In this specification, drought results in a discrete downward shift in the intercept. The model is specified as:

$$Q = a + b\,T + c\,D + u$$

Where 'T' refers to the time trend that captures the effect of technological change and other exogenous intercept shifters, 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.

Household-level analysis

Analysis of the household-level impact of drought and of farmers' coping mechanisms is conducted using cross-sectional data from a survey of 1,316 farm households in the three countries.[2] 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 were elicited during the survey using pretested survey questionnaires.

Farmers were asked to provide information on production practices and farm productivity for normal and drought years. The meteorological definition of drought used for aggregate analysis is inappropriate in estimating 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, for comparative purposes, normal and drought years were identified through the perceptions of villagers, and the specific years considered vary across locations. A village-level consensus on the normal and drought year was achieved through focus-group discussions. Information on the overall impact of drought on income and how households attempted to cope with it was also collected during the survey.

2 The primary data were collected from a survey of 1,316 farm households, which included 153 households covering Guangxi, Hubei and Zhejiang provinces in southern China; 863 households covering Chattisgarh, Jharkhand and Orissa states in eastern India; and 300 households covering most of the provinces in north-eastern Thailand.

V. Major empirical findings

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 0.1-0.4, with the probability being higher in eastern India relative to southern China and north-eastern Thailand (Figure 1). The probability of late season drought is higher than that of the early season generally. Late season drought is also found to be spatially more covariate. As rice yield is more sensitive to drought during the flowering and grain-formation stages (i.e. in late season, according to the definition used here), late season drought is generally more damaging than that in early season.

Temporal instability in rice production, as measured by the de-trended coefficient of variation of rice yield, is high in eastern India relative to the other regions. The nature of instability is typically illustrated by the yield trend in Orissa (Figure 2). Such a high level of instability over the whole of the 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 north-eastern Thailand are much lower (Table 4), indicating that droughts in these regions are 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 will also be higher in eastern India relative to the other two regions.

Estimates of aggregate production losses

Drought causes production losses of rice and other major crops grown during and after the rainy season. The estimation of aggregate production loss involved analysis of the published temporal data on rainfall and crop production. The estimated average loss in rice production during drought years for the three states of eastern India is 5.4 million tons (Table 5). This is much higher than for north-eastern Thailand (less than 1 million tons) and southern China (about 1 million tons, but not statistically significant). The loss during drought years (including non-rice crops) is thus 36 per cent of the average value of production in eastern India. This represents a massive loss during drought years (estimated at US$856 million).

As drought does not occur every year, the above estimate of production loss needs to be averaged over a span of drought and non-drought years to obtain the annual average loss estimate. Again, for eastern India, this represents an annual average loss of US$162 million (or 7.0 per cent of the average value of outputs). For north-eastern Thailand and southern China the loss is much smaller, at less than US$20 million per year (or less than 1.5 per cent 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. Higher probability of drought,

Figure 1
Estimated probability of early and late season drought in southern China (1982-2001), eastern India (1970-2000) and north-eastern Thailand (1970-2002)

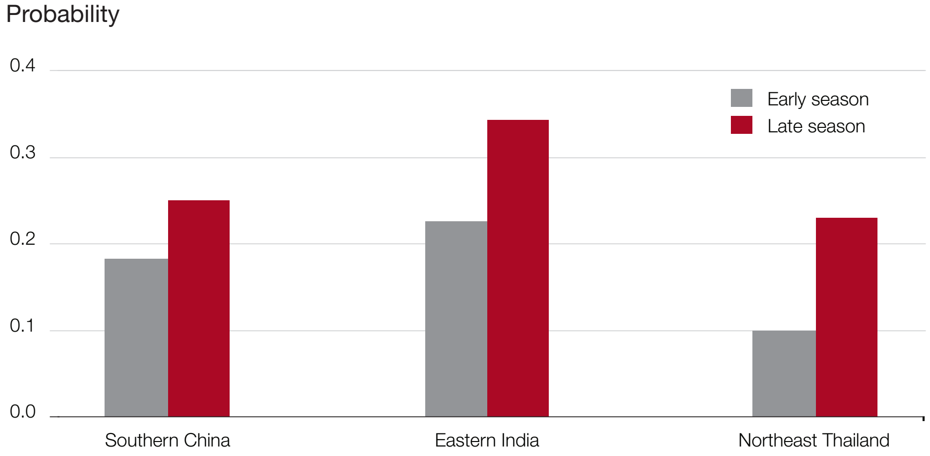


Figure 2
Trends in rice yield and major drought years, Orissa, eastern India (1970-2003)

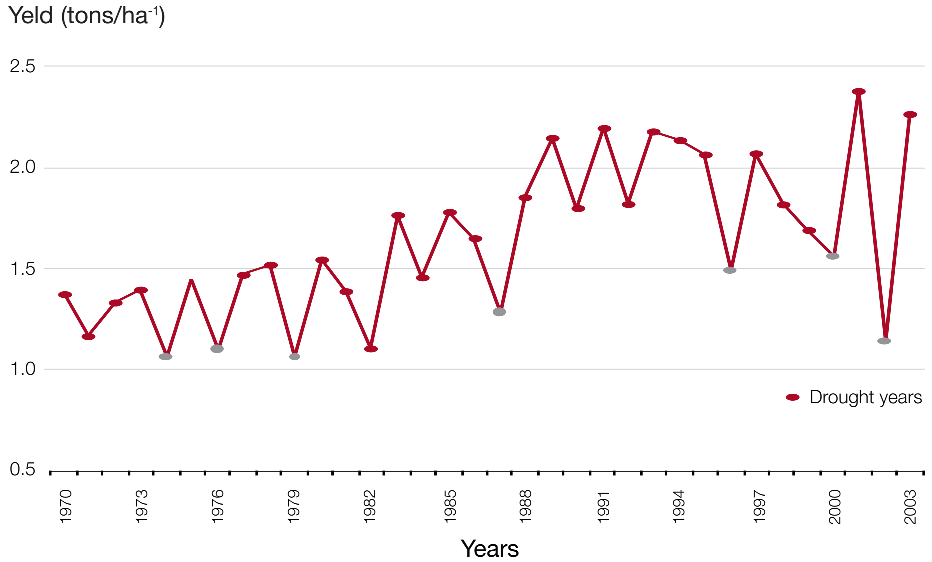


Table 4
Coefficient of variation of rice area, yield and production 1970-2003[a]

Rice	Southern China	Eastern India	North-eastern 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.
Sources:
China: NBS (2005).
India: NCAP-IRRI (2002) and INDIAAGRISTAT (2005).
Thailand: OAE (2004).

larger magnitude of loss during drought years, and a more covariate nature of drought have led to a higher production loss at the aggregate level in eastern India.

Household-level impact of drought

A detailed analysis of the household-level impact of drought was conducted using farm survey data. Households suffered rice production losses of from 44 to 71 per cent (Table 6). Even in southern China and north-eastern 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. Across the toposequence, production losses were higher in upper fields that drain quickly than in bottom lands, which tend to have more favourable hydrological conditions.

The household-level impact of drought presented here is based mainly on the study in eastern India. Relative to that area, impacts in north-eastern Thailand and southern China were found to be quite small and hence are not discussed here – even though they are much higher than aggregate level losses.

The loss in rice yield during drought years was estimated to be in the range of 25-40 per cent in Jharkhand and Orissa, but was almost 100 per cent in Chattisgarh, where there was almost complete crop failure during the 2002 drought. In Jharkhand and Orissa, farmers did not suffer from crop failure, but the yield loss, in combination with a reduction in area, resulted in an overall production loss of some 60 per cent. The bottom two income quartiles account for over half the households that lost more than 80 per cent of their rice output (Figure 3). This highlights the regressive impact of drought.

Drought resulted in total income loss of about 24 and 26 per cent in Jharkhand and Orissa respectively (Table 7). The magnitude of loss was much higher in Chattisgarh, at 58 per cent, 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 in that state. The drop in rice income is the main factor contributing to this magnitude. The loss in rice alone accounted for 44 per cent, 75 per cent and 82 per cent of the income drop in Orissa, Jharkhand and Chattisgarh respectively. Overall, the drop in total agricultural income in the three states was in the range of 40-80 per cent. Earnings from farm labour also dropped substantially, due to the reduced labour demand. However, there was some small compensation resulting from an 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 non-farm sector. This mainly included employment as wage labour in the construction sector, for which farmers often migrated to distant sites. The additional earning from non-farm employment is clearly inadequate to compensate the loss in agricultural income, thus resulting in a drop in total income in the range of 24-58 per cent.

Farmers relied on three main mechanisms to recoup this loss in total income: sale of livestock, sale of other assets and borrowing. These adjustment mechanisms helped recover only from 3 to 7 per cent of the loss in total income. Compared with normal years, households still ended up with a substantially lower level of income. 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.

Table 5
Estimated value of crop production losses due to drought using rainfall-based drought years 1970-2002[a]

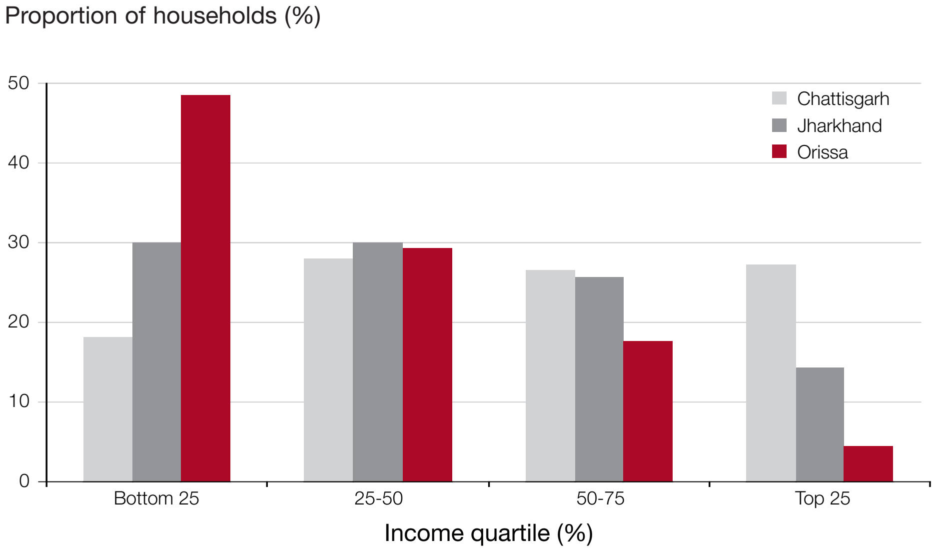
Country	Drought years			Annual	
	Quantity of rice production loss (million t)	Value of crop production loss[b] (million $)	Ratio of loss to average value of production (%)	Value of crop production loss[b] (million $)	Ratio of loss to average value of production (%)
Southern China	1.2	133	3	16	0.4
Eastern India	5.4	856[c]	36	162	7.0
North-eastern Thailand	0.7	85[c]	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 non-rice crops for India, whereas only rice crops were used for China and Thailand.
c Means are statistically significant at the 10% probability level.
Sources:
China: NBS (2005).
India: NCAP-IRRI (2002) and INDIAAGRISTAT (2005).
Thailand: OAE (2004).

Table 6
Percentage change in rice area, yield and production among sample farm households in drought year compared with normal year

Rice	Southern China	Eastern India	North-eastern Thailand
Area	-19	-36	-21
Yield	-31	-54	-45
Production	-44	-71	-56

Figure 3
Distribution of households incurring over 80% of rice production loss during drought year, by income quartile, eastern India



This analysis provides a general picture of the overall impact of drought on farm income. The 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 proportionate effect on the income of smaller farm-size categories, as they derive relatively less income from crop production. This is indeed the case shown in the analysis by farm-size categories (Table 8). As a result of less reliance on crop production and their ability to compensate partially for farm income losses through increased non-farm labour work, the proportionate loss in total income of small-scale and marginal farmers was less than that of medium- and large-scale farmers. For example, the total loss in income of the former was 17-42 per cent, while that of the latter was 25-67 per cent.

Despite this lower proportionate loss, the welfare effect of income loss is likely to be much more severe for small-scale and marginal farmers, who earn a much lower level of income even during normal years. For example, marginal farmers earned only 16-25 per cent 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 groups. The differential impact of an income drop on the incidence of poverty is examined in the next section.

Poverty impact of drought

The incidence of poverty increased substantially during drought years (Table 9). Estimates indicate that almost 13 million additional people fell back into poverty in these three states as a result of drought. 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. The effect of drought on the incidence and severity of poverty is illustrated graphically through an example from Jharkhand (Figure 4). 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 years, as some people who were above the poverty line fell back into poverty. Others already below the poverty line were pushed deeper into poverty. Some of the increase in poverty may be transitory, with households being able to escape from 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).

Household vulnerability to drought

'Vulnerability' refers to the capacity of a population to anticipate, cope with, prevent major decline in well-being, and recover from the adverse impact of shocks (Blaikie et al. 1994, World Bank 2001, Tesliuc and Lindert 2004, Brooks, Adger and Kelly 2005). Vulnerability is not a new concept, but interest and concern have been growing in recent years. Drought vulnerability refers to the degree to which households are susceptible to the 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 (Alwang, Siegel and Jorgensen 2001, Kamanou and Morduch 2002, Brooks, Adger and Kelly 2005, Christiaensen and Subbarao 2005, World Bank 2005). The degree of availability, accessibility and affordability of knowledge, resources and technologies also defines

Table 7
Average income per household in normal and drought year, eastern India
(US$)

Income sources	Normal year			Drought year			Change over normal (%)		
	CH[a]	JH	OR	CH	JH	OR	CH	JH	OR
Regular 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
Non-rice	170	60	170	60	10	100	-65	-83	-41
Farm labour	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
Non-agriculture	180	190	200	220	220	220	22	16	10
Hired labour	50	120	110	90	150	150	80	25	37
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		
Other[c]	10	0	0	10	0	0	0		
Income from asset sale and/or borrowing	30	20	60	70	30	80	136	51	33
Sale of livestock[d]	10	10	10	10	10	20	3	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 operation	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 Includes goats, sheep, chickens, ducks, calves, kids and their produce (milk, ghee, egg, etc.).
c Includes sale of fruit, sale of fish, old-age pension, small business, small artisanry and so on.
d Includes large animals such as cattle, buffalo, bullocks and pigs.
e Includes land and buildings.
f Includes farm implements, jewelry and other small assets.

Table 8
Percentage change in average annual gross income per household in drought year compared with normal year, by farm-size category, eastern India

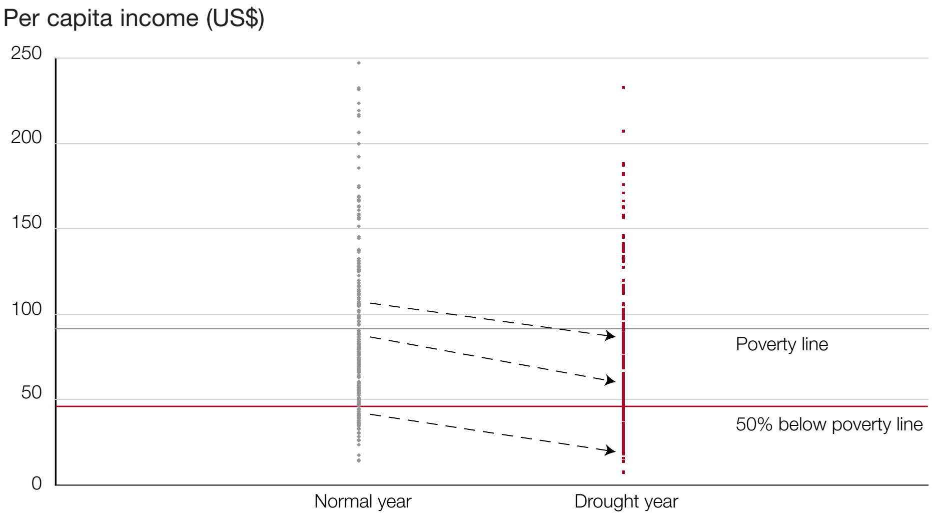
Income sources	Marginal	Small	Medium	Large	All
Chattisgarh					
Agriculture	-65	-71	-85	-81	-79
Non-agriculture	46	38	16	12	22
Total	-26	-42	-63	-67	-58
Jharkhand					
Agriculture	-45	-43	-45	-50	-48
Non-agriculture	23	20	9	17	16
Total	-18	-17	-26	-25	-24
Orissa					
Agriculture	-44	-37	-42	-40	-43
Non-agriculture	24	9	-16	-15	10
Total	-17	-21	-35	-34	-26

Table 9
Incidence of rural poverty among sample households in normal and drought year, eastern India

States in eastern India	National estimate of rural poverty ratio (%)[a]	Sample estimate of poverty ratio[b]		Percentage point increase (% point)	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 The poverty ratios for Chattisgarh and Jharkhand are based on values for undivided states of Madhya Pradesh and Bihar respectively. The national poverty ratio value is based on estimates made during 1999-2000.
Source: Planning Commission (2002).
b Monthly rural poverty-line incomes of Rs 311.34, 333.07 and 323.92 are used to define the poverty line for Chattisgarh, Jharkhand and Orissa respectively.

Figure 4
Effect of drought on incidence and severity of poverty, Jharkhand, India



Note: each dot represents a household.

vulnerability. These include not only physical, financial and human capital, but social capital as well. The relationship between these assets and vulnerability is fairly complex and context dependent. A simpler approach, taken here, is to identify vulnerable households using an income cut-off level. To link vulnerability with poverty, in this study the cut-off level of income was set somewhat arbitrarily at 20 per cent above the poverty line. This is a pragmatic approach to identifying vulnerable households – although theoretically somewhat deficient – because low income levels are one manifestation of vulnerability. Households whose incomes are below this level are defined as vulnerable.

The major characteristics of the two groups of households are summarized in Table 10. 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.

Table 10
General characteristics of vulnerable and non-vulnerable farm households, eastern India[a]

Characteristics	Household type	
	Vulnerable	Non-vulnerable
Household (hh) size (no.)	7.1	5.6
Average age of hh head (years)	49.4	47.0
Average education of hh head (years of schooling)	3.2	4.5
Ratio of women (% of hh size)	48	46
Economically active population (% of hh size)	56	66
Farm size (ha/hh)	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]	21 662	42 711
Farm income	14 494	27 799
Non-farm income	6 108	12 372
Other income[c]	1 060	2 540

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

The total household income of the vulnerable group is half that of the non-vulnerable group. Their broader income strategies, in terms of farm or non-farm orientation, are similar, as indicated by the almost equal shares of non-farm income in total income. However, the relative importance of various components of income is different in the two groups (Table 11). Vulnerable households derive a smaller share of income from agricultural production, but relatively more as hired labour in farm and non-farm activities. Their income shares from self-employment, business enterprises and government jobs are much smaller than those of the non-vulnerable groups. The difference in income strategies is the result of the smaller (and less favourable) 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 analyse the determinants of vulnerability. This econometric analysis supports the findings of the tabular analysis presented earlier. The results indicate that households with small farm size, a high proportion of upland area, and a small proportion of lowland area are more vulnerable to drought. Suitable, targeted safety nets may be needed to protect such households.

Farmers' coping strategies

Farmers who are exposed to drought risk use different combinations of ex-ante and ex-post coping strategies. Based on farm survey data, this section presents various drought coping strategies used by farmers in eastern India.

Crop management adjustments

Analysis of farmers' various adjustments in rice production practices indicates that, overall, farmers do not seem to have much flexibility in making management

Table 11
Percentage share in average annual gross income per household during normal year, by household vulnerability, eastern India

Income sources	Household vulnerability	
	Vulnerable	Non-vulnerable
Agriculture	67	65
Crop income	46	57
Farm labour	16	5
Other farm income[a]	5	3
Non-agriculture	28	29
Hired labour	20	9
Other non-farm income[b]	8	20
Other sources	5	6
Sale of livestock[c]	2	2
Sale of major/minor assets[d]	1	3
Mortgage/borrowing	2	2
Total income (US$)	21 662	42 712

a Includes income from small animals, animal products and forest produce.
b Includes income from business, services, self-employment, small business, old-age pensions and artisanry.
c Includes large animals such as cattle, buffalo, bullocks and pigs.
d 'Major assets' include land and buildings; 'minor assets' include farm implements, jewelry and other small assets.

adjustments in the rice crop in relation to drought. This could partly be due to the fact that drought mostly occurs in the late season, by which time opportunities for crop management adjustments 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 have probably limited flexibility to make tactical adjustments in crop management practices. As a result, most farmers seem to have developed an outward-looking strategy of generating income through migration in times of drought.

Opportunities may exist, however, to make adjustments to the post-rainy-season crop that follows rice 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 to produce a higher yield before it is depleted by evaporation. In addition, early harvesting of the post-rainy-season crop – made possible by early planting – increases household food availability earlier. Although farmers make use of these opportunities for loss recovery where possible, effective use of this strategy is somewhat limited, as most of the land is left fallow during the post-rainy season due to several constraints, including labour shortages resulting from seasonal migration. In major drought years, people who have migrated to distant places would simply not have returned early enough to use 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.

Consumption adjustments

Since rice is a staple food, a production loss can be expected to result in major adjustments in the household food balance. These adjustments could range from reduced sale of rice, through a 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, and supplementation of the food deficit by other types of food not normally consumed, to, in the worst-case scenario, a reduction in consumption.

Results from the survey indicate that all these types of adjustments are made to varying degrees. 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 per cent compared with normal years. This reduction in marketed quantity would obviously have a price effect in the local market, which, if not counteracted by inflow of grains from other areas, would result in an overall reduction in consumption per capita. This price effect is likely to have a regressive impact on the welfare of poor labourers and marginal farmers, who spend a larger share of their income on rice.

Farmers even reduced the quantity retained as seed for planting during the subsequent year (by 40-93 per cent). This kind of adjustment may be considered a rather desperate response, as production during the subsequent year will almost certainly suffer when the grains meant for seed are consumed.

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 millet area occurs during drought years. In Orissa, the consumption of millet increased by 15 per cent. 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 per day and the quantity consumed per meal. About 54-70 per cent of households reduced the number of meals per day. As a result, the average number of meals dropped from close to three to close to two, with 10-30 per cent of households reducing their frequency of food intake to one meal per day (Table 12). A large proportion of households (60-70 per cent) also reduced the quantity of food consumed per meal. In addition, the consumption of food items not normally eaten is a common practice in coping with a loss in food production.[3]

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

The impact of drought tends to vary according to class, age, ethnicity and gender, as these factors determine peoples' vulnerability. Although quantitative information was not available, farmer interviews indicated that the impact on women and young children tends to be more severe than on others. This is due to their sociocultural and economic positioning within the family and community. In a typical rural family, women are generally the last to eat their meals and hence are likely to receive a much

3 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.

smaller quantity of food during shortages. Drought also results in poorer health conditions for women because of their somewhat subordinate position in the family. When men migrate during drought years, women become the de facto heads of households, and this increases their workload, as they have to manage the farm in addition to conducting their usual household chores (Rogaly et al. 2002, Deshingkar and Start 2003, Shah and Shah 2005). Prolonged malnutrition and increased workload during drought adversely affect women's health, especially that of pregnant and lactating mothers. Infants and young children also suffer adversely as a result.

Expenditure adjustments

Forced adjustment in expenditure is a logical consequence of income loss. Reduced expenditures on some non-essential items such as clothing and social functions will not have much welfare effect. However, farmers often reduce expenditures even on essential items such as food and medical treatment. Such cuts are most likely to have adverse short- and long-term consequences. More than 50 per cent 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 the absolute amount may be small. Second, adolescent children may be pulled out of school as labour to augment family income. Third, children leave school to accompany their migrant parents, who are unlikely to be able to re-enroll 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 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.

Credit

Borrowing to smooth seasonal fluctuations in agricultural income is a normal and regular activity in rural areas. Borrowing may be in both cash and 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 or seed, other food crops, and seeds of other crops. However, reliance on borrowing as a drought management strategy varied across states. For example, 7-30 per cent more farmers practiced cash and kind borrowing across the three states of eastern India.

Borrowing does not have adverse welfare consequences when credit markets are competitive. However, adverse economic and social consequences can arise in rural areas where such 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 in borrowing during drought years increases by 5-9 percentage points. In Orissa, farmers reported an average interest rate of as much as 34 per cent per annum during drought years. Such a high interest rate obviously could force poor farmers into a perpetual debt trap.

Asset depletion

Liquidation of assets is an important mechanism in 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 these assets does not entail economic costs. However, in times of distress, farmers often

Table 12
Household consumption behaviour in normal and drought year, eastern India

Household consumption behaviour	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 meals per day during drought year (%)	54	60	70
Percentage of households with given frequency of meals per day (%)			
Frequency of meals per day in normal year			
1	0	0	0
2	26	34	47
3 or more	74	66	53
Frequency of meals per day in drought year			
1	10	11	33
2	57	73	52
3	33	16	15
Percentage of households reducing quantity of food per meal during drought year (%)	61	62	74
Percentage of households consuming unusual foods in drought year that are not normally eaten (%)	21	58	46

Table 13
Percentage point change in frequency of households engaged in selling of productive assets in drought year compared with normal year, eastern India[a]

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

a Positive numbers indicate an increase in frequency during drought years.
b Refers to large animals such as cattle, buffalo, bullocks and pigs.

liquidate productive assets such as agricultural tools, draft animals and even land. The sale of these assets can have a negative impact on agricultural productivity in subsequent years. The incidence of liquidation or mortgaging of these productive assets during drought years was found to increase in all study villages (Table 13).

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 grasses to their livestock increased. Similarly, fewer households were able to provide the oil cakes normally used as feed supplements. Instead, open grazing on dry leaves, grasses and other plant species of low nutritional value becomes the norm in drought years. Farmers reported a decline in the weight of draft animals and their strength as a consequence of poor feeding. They also reported an increased incidence of illness and mortality of livestock.

Use of forests 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 and the household food supply. The number of farmers relying on forest products increased substantially in Orissa. In comparison, reliance on forest and forest products was much less in Jharkhand.

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

Seasonal migration

Seasonal migration is widely practiced in all three states even in normal years. It is an important source of income, especially for small-scale and marginal farmers with a small land base. 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 6-18 percentage points, while the number of working days increased from 32 days in normal years to 94 in drought years. This forced migration, while helping households cope with drought, can result in long-term adverse consequences, socially and economically. Invariably, a migrant labourer is paid lower wages than local labour. Migrant families that migrate to distant places sometimes do not return in time to resume their normal agricultural activities even when the drought is over. Moreover, migrant labourers generally end up in jobs that are physically more demanding and with long working hours. They also suffer from poor living conditions, such as those in ghettos, and lack social integration into local communities.

Reliance on relief support

Government-sponsored relief programmes can serve as an important safety net. Although the Government of India spends substantial resources on relief programmes (Samra 2004), it does not seem to have reached needy people adequately. In the states studied, the number of households that participated in drought relief programmes was relatively low and ranged from 10 to 28 per cent. The limited coverage and amount of assistance received per household generally reduced the effectiveness of these programmes.

Relative to eastern India, farmers in southern China and north-eastern 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 the three regions are summarized in Table 14. In eastern India, production losses in drought years translate into consumption losses despite the deployment of a range of coping mechanisms. The major coping mechanisms deployed to reduce income shortfall include migration, sale of draft animals and borrowing. However, incomes generated through these mechanisms are not adequate to compensate the loss, and farmers are forced to reduce consumption.

In southern China and north-eastern Thailand, on the other hand, sale (or mortgage) of land is not practiced in response to drought. In the case of China, land is not individually owned and thus no sale can take place. In Thailand, farming is mechanized to a considerable extent, and thus 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 non-rice farm production and non-

Table 14
Major drought coping mechanisms of farm households[a]

Drought coping strategies	Southern China	Eastern India	North-eastern Thailand
Migration	+	++	+
Asset sale			
Livestock	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 programme	0	+	0
Artificial rainmaking	+	n.a.	+

a - indicates a decrease, + indicates an increase, and 0 indicates no change. Double signs indicate larger change, while a single sign indicates marginal change; 'n.a.' indicates 'not applicable'.

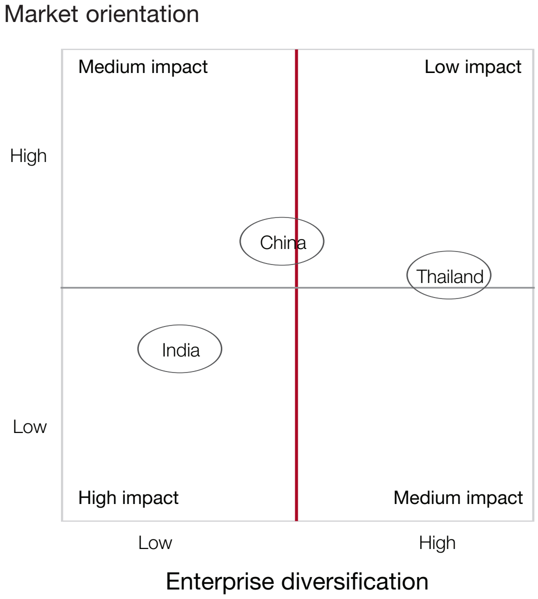
Table 15
Percentage share of rice and non-rice income in total income of farm households

Income source	Southern China	Eastern India	North-eastern Thailand
Rice income	22	40	21
Non-rice farm income	32	22	28
Non-farm income	46	38	51

farm activities. In-crop adjustments in rice production and crop substitution during drought years do not play significant roles in coping with drought in the three regions. Farmers seem to follow a set of major cropping practices, with few adjustments in the event of drought.

In the case of eastern India, rice accounts for 40 per cent of total household income (Table 15). The share of rice in this income in southern China and north-eastern Thailand is about half that of 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 more severe relative to the other two regions. In both north-eastern Thailand and southern China, agricultural income has become more diversified and includes income from commercial field crops that are less sensitive to drought than rice. In addition, the share of non-farm income in total income is much higher. Thus a more commercialized agriculture and a greater diversification of farm income were factors contributing to the smaller impact of drought on consumption in these two countries relative to eastern India. The effect of these factors on household-level impact is summarized in Figure 5.

Figure 5
Household-level consequences of drought



Overall economic costs of drought

The total economic cost of drought includes: the value of production losses during drought years; ex ante costs associated with the opportunity loss of lower average productivity and the use of conservative practices; the cost of drought relief provided by the government and other agencies;[4] and the cost of mitigation programmes implemented to reduce production losses. The average annual cost for the three states of eastern India included in this study is in the neighborhood of US$400 million (or 11 per cent of agricultural GDP). The share of the value of production loss in this total is about 40 per cent. Overall, the cost of drought is a substantial proportion of the agricultural value added in eastern India.

Relative to eastern India, the economic cost in southern China and north-eastern Thailand is small, in both absolute and relative terms. Production losses at the aggregate level are small due to the lower frequency and less covariate nature of drought in these two regions. In addition, the magnitude of any opportunity costs associated with rice production is 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 two regions are thus major factors determining the magnitude of economic loss.

Institutional responses to drought

There are a number of similarities in public-sector responses to drought in all three countries. 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 centred on water resource development. These include

4 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 in providing relief.

major and minor irrigation schemes, farm ponds and overall development of watersheds for improving the retention and effective use of water. During the 1960s and 1970s, large-scale irrigation schemes were developed to increase overall farm productivity, using the potential created by the green revolution. Protection from drought was not the primary reason for such investments. Over time, the emphasis shifted towards developing small and minor irrigation schemes, farm ponds and watershed-based approaches. This change in approach is partially due 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 are major responses in eastern India, farm ponds are being promoted in north-eastern Thailand, and local water resources such as farm ponds, reservoirs and groundwater have been developed and used more effectively in southern China.

Although water resource development is seen as part of a 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 livelihood of millions of poor people is 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. Such assistance is needed to prevent hunger and starvation. However, it is now widely accepted that the provision of relief follows a 'firefighting' approach of dealing only with the immediate problem. Although food-for-work programmes are meant to contribute to long-term drought-proofing through the building of assets, success on this score has been limited owing to several design limitations, implementation difficulties and limited coverage as a result of budgetary constraints. Considerable opportunities exist to improve 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 into overall agricultural development programmes.

In the case of southern China and north-eastern 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 the benefit of the community. Such community-level involvement is relatively weak in the other two regions. Given the higher income level and the relatively low share of agriculture in the national income of Thailand, in drought years water for industrial and domestic uses, rather than for agriculture, often dominates policy debates.

VI. Drought mitigation options

Agricultural research

Improved rice technologies that help reduce losses from 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, Lafitte et al. 2006). 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. 2006). The probability of success in developing such germplasm is likely to be substantially higher now than it was ten years ago. Complementary crop management research – to manipulate crop establishment, fertilization and care to avoid drought stress, to use available soil moisture better, and to enhance 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 per cent of their agricultural GDP in research, the ratio of research expenditure to agricultural GDP ('research intensity') in developing countries has been estimated at 0.62 per cent (Pal and Byerlee 2003). For China and India, research intensities are only 0.43 and 0.29 per cent respectively. Clearly, agricultural research in the developing countries of Asia remains underinvested. In addition, in order to achieve significant impact, an institutional set-up is needed that promotes multidisciplinary research and brings in other stakeholders – such as natural resource managers and representatives of non-governmental organizations and farmer associations – to undertake more practical, problem-solving research.

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: the allocation of resources for rice research to rainfed areas in India is disproportionately small relative to the potential contribution of these areas to efficiency and equity impact (Pandey and Pal 2007). The share of even this limited amount that goes to addressing abiotic constraints such as drought and submergence is less than 10 per cent.

It has been established that the marginal productivity of research resources may now be higher in rainfed environments than in irrigated ones, and that agricultural research in unfavourable (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 on productivity growth.

Technology design considerations

Several design features should be considered in developing improved technologies for effective drought mitigation. An important criterion is that technologies should improve flexibility in decisions regarding crop choices, timing and method of crop establishment, and the timing and quantity of various inputs. Flexibility in agricultural technologies permits farmers not only to reduce the likelihood of low income, but also to adaptively capture income-increasing opportunities when they arise. Technologies that lock farmers into a fixed set of practices and timetables do not permit effective management of agricultural risk. In fact, the empirical analyses presented earlier indicate that farmers do not seem to have much flexibility in making management adjustments in rice cropping in relation to drought. The timing of drought (mostly late rather than early) and the lack of suitable technological options have probably limited farmer flexibility in making tactical adjustments in crop management practices to reduce losses. Examples of technologies that provide greater flexibility would be: varieties that are not adversely affected by delayed transplanting in response to 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 important factors that contribute to increased poverty in drought years. Technologies that reduce yield losses can avoid such adverse impact on poverty, even if there may be some associated trade-offs in yield during favourable years. Hence, in terms of poverty impact, if there are trade-offs involved in achieving both simultaneously, higher priority should be accorded to research focused on cutting off the lower tail of the yield distribution than on raising the average yield by improving performance during normal years.

Results show 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 consequences of low or no harvest, farmers also lose their investments in seed, fertilizer and labour 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 labour 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 – again, if tolerance to early and late season drought cannot be achieved simultaneously.

In rainfed areas, the land endowment of farmers typically consists of fields across the toposequence having different hydrological conditions. Fields in the upper part of the toposequence are typically more drought-prone than those in the lower part. Farmers exploit 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 labour demand, grain quality, taste and suitability to various uses. Breeding programmes that produce a wider choice of plant materials that correspond to field hydrological features and have different characteristics and varying responses to drought can play an important role in effective protection.

Crop diversification is an important drought coping mechanism. Rice technologies that promote and do not constrain such diversification are needed. In rainfed areas, shorter-duration rice varieties can facilitate planting of a second crop using residual moisture. Similarly, rice technologies that increase labour productivity as well as yield will facilitate crop and income diversification. Higher labour productivity in rice production will relax any eventual labour constraint on diversification. Examples of such technologies are selective mechanization, direct seeding and chemical weed control.

Water resource development

Development of water resources is an important area of protection against drought that is emphasized in all three countries. The large-scale development of irrigation schemes that was a hallmark of the green revolution is limited now by high costs and increasing environmental concerns (Rosegrant, Cai and Cline 2002, Gulati, Meinzen-Dick and Raju 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 (Shah 2001, Moench 2002). Similarly, watershed-based approaches implemented in drought-prone areas of India are providing opportunities to achieve long-term drought-proofing by improving overall moisture retention within watersheds (Rao 2000).

Public-sector support for further development, maintenance and rehabilitation of small and minor irrigation 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 (Kerr, Pangare and Pangare 2002). Farmer-managed irrigation systems based on traditional institutions have been found to be efficient, effective and sustainable in managing irrigation in several Asian countries, including India.

Drought characterization, analysis and mapping

Although drought occurs regularly and governments respond by providing relief and other forms of assistance to affected communities, detailed scientific characterization of drought, analysis of its impact, and mapping are not being adequately carried out at either the local (province, district, state) or national level. Such analyses and mapping are critically important in 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. Research is much more advanced in India, but it focuses mainly on arid and semi-arid zones. No major agencies are conducting in-depth analysis of the nature and impact of drought in subhumid zones. Establishment of such agencies and linking them with organizations involved in drought management at various levels would improve such management overall.

Drought relief and long-term drought mitigation

In all three countries studied, a major response to drought has been to provide relief to the population affected. India has the most elaborate institutional set-up for drought relief, which mainly takes the form of employment generation through public works. Some inputs and credit are provided as well. While the provision of relief is essential in reducing the incidence of hunger and starvation, major problems with the relief programmes are slow response, poor targeting of beneficiaries and limited coverage due to budgetary constraints. The firefighting approach that underlies the provision of drought relief cannot provide long-term drought-proofing, despite the large amount spent in drought years (Rao 2000, Hirway 2001).

It is important that provision of relief in such years be complemented by: a long-term strategy of investment in soil and water conservation and use; policy support; infrastructure development to promote crop and income diversification in drought-prone areas; and encouragement of community participation in managing and developing local water resources. Important progress is being made through watershed development programmes in diverse areas of India, but these programmes are not sufficiently integrated into overall agricultural development activities, thus diluting their potential impact (Rao 2000). In addition, a decentralized institutional set-up is needed that promotes greater participation and decision-making by local-level agencies in order to improve the overall effectiveness of relief programmes, which tend to be top-down in design.

Drought forecasting and preparedness

Scientific advances in meteorology and informatics have now given drought forecasting a reasonable degree of accuracy and reliability. Various indicators such as the Southern Oscillation Index (SOI) are routinely used to forecast drought in several countries (Wilhite 2000, Meinke and Stone 2005). Suitable refinements and adaptations of these forecasting systems are needed to enhance drought preparedness at the national level and to assist farmers in making more efficient decisions regarding the 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 manage the risk more effectively.

Policies for promoting income diversification

While technological interventions can be critical in some cases, this is not the only option for improving management of drought. There is a whole gamut of policy interventions that can improve farmers' management capacity through more effective income- and consumption-smoothing strategies (Reardon, Delagado and Matlon 1992). Diversification of rural income towards activities that generate negatively or poorly correlated income streams is an efficient mechanism for dissipating risk. Policies that promote rural income diversification are needed, both for general income growth and for efficient risk management. Improvements in rural infrastructure and marketing facilities, as well as promotion of rural and agroprocessing industries 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, which will further increase farmers' capacity to cope with agricultural risk. The widening and deepening of rural financial markets will also be a critical factor in reducing fluctuations in both income and consumption over time (Barrett 2005, Haggblade, Hazell and Reardon 2007).

Crop insurance

Insurance provides a safety net through the 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 conventional forms of crop insurance are unlikely to be successful owing to problems of moral hazard and adverse selection (Hazell, Pomerada and Valdes 1986), innovative approaches such as rainfall derivatives and international reinsurance of agricultural risk are promising (Walker and Ryan 1990, Skees et al. 2001, World Bank 2003, Glauber 2004). However, these alternative schemes have not yet been adequately evaluated. There are important challenges to be faced in employing weather risk markets in developing countries (Varangis 2002). More work is needed to develop and test new types of insurance products and schemes suited to the hundreds of millions of small farmers of Asia who grow rice primarily for subsistence.

VII. Concluding remarks

Drought is one of the major climatic hazards even in the subhumid rice-growing areas of Asia. It is an event that recurs every three to ten years, affecting agriculture and the livelihoods of millions of farmers and agriculture labourers. The socio-economic impact of drought is enormous. It has huge economic costs, in terms both of actual economic losses during drought years and of losses arising from forgone opportunities for economic gains. The total economic cost of drought for eastern India is estimated at 11 per cent of agricultural GDP. Drought impact on rice production is substantially higher at the farm level than at the aggregate level. Farm households use various coping strategies to deal with the consequences of drought: careful choice of cropping patterns, rice varieties, planting date, planting method and crop management practices. Increased dependence on wage income, asset depletion and public relief are the major mechanisms used to meet the shortfall in income. The relative importance of these strategies varies across the region, with asset depletion and public relief being more important in India than in China or Thailand. However, these coping mechanisms are inadequate in preventing a reduction in income and consumption, especially in poor and vulnerable groups.

Drought contributes directly to an increase in the incidence and severity of poverty. In the three states of eastern India alone (Chattisgarh, Jharkhand and Orissa), drought results in an additional 13 million people falling back into poverty. This translates into an increase in rural poverty in the three states combined of 19 percentage points – and at the national level of 1.6 percentage points. Not all people who fall into the 'poverty trap' in drought years are able to escape once the weather returns to normal. In addition, people who are poor even during normal years get pushed deeper into poverty in drought years.

The overall economic and social costs of drought remain high – despite considerable expenditure to provide relief to drought-affected areas, improve soil moisture availability through watershed programmes, and generally reduce vulnerability to drought through agricultural development. The provision of relief has been the main government drought management approach. Although important in reducing hunger and hardship among the populations affected, provision of relief alone is clearly inadequate and may even be an inefficient response for achieving longer-term drought mitigation. Given the strong linkage between drought and poverty, it is critically important to include drought mitigation as an integral part of overall 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.

Research to develop improved technologies can help provide protection from drought. Scientific progress in understanding the physiology of drought and in developing biotechnology tools offers the promise of significant impact in drought mitigation. However, agricultural research in general remains grossly underinvested in the developing countries of Asia. This is cause for concern, not only for drought mitigation, but for promoting overall agricultural development.

Improvement in rice production technology is but one of the components of an overall strategy for effective drought mitigation. Increased moisture availability to crops through water conservation and harvesting and watershed development is an important component. The potential is limited for large-scale development of conventional sources of irrigation based on large dams and shallow groundwater in drought-prone areas, at least in the near future. Better management of local rainfall can accomplish much – through water harvesting and moisture conservation measures.

In addition to technological interventions, a range of viable 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. Investment in rural education can similarly help diversify income. In addition, such investments contribute directly to income growth, which will further increase farmers' capacity to cope with agricultural risk. The widening and deepening of rural financial markets will also be a critical factor in reducing fluctuations in both income and consumption over time. Although conventional forms of crop insurance are unlikely to be successful owing to problems of moral hazard and adverse selection (Hazell, Pomerada and Valdes 1986), innovative approaches such as rainfall derivatives and international reinsurance of agricultural risk are promising. Improvements in drought forecasting and efficient provision of such information to farmers can 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 maximum impact. Although some progress has been made during the past decade, much remains to be done.

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