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DISCUSSION PAPER

Economic Cost of Drought and Farmers' Coping Mechanisms: A Study of Rainfed Rice Systems in Eastern India

Sushil Pandey, Dev Dutt Behura, Renato Villano, and Dibakar Naik

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Mailing Address: MCPO Box 3127, 1271 Makati City, Philippines
Phone: (63-2) 845-0563, 844-3351 to 53
Fax: (63-2) 891-1292, 845-0606
Email: IRRI@CGIAR.ORG
Telex: (ITT) 40890 Rice PM: (CWT) 14519 IRILB PS
Cable: RICEFOUND MANILA
URL: http://www.cgiar.org.irri
Riceweb: http://www.riceweb.org
Riceworld: http://www.riceworld.org
Courier address: Suite 1099, Pacific Bank Building
6776 Ayala Avenue, Makati
Metro Manila, Philippines
Tel. (63-2) 891-1236, 891-1174, 891-1258, 891-1303

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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. While humans have attempted to reduce the adverse effect of weather on agriculture through scientific research and technology development, the performance of agriculture still depends largely on the weather. This dependence is greater when crops are grown under rainfed conditions. Even under irrigated conditions, crop output can fluctuate widely as the supply of irrigation water is often determined mainly by rainfall.

Rice, wheat, and maize are the major food grains for most of the world population. Although the output of these crops has increased over time, some years have had a major shortfall caused by climatic aberrations such as drought and flood. In recent years, such events have attracted much attention, especially when they have led to widespread starvation and death in poorer countries. While the extent to which famines are man-made or natural is arguable, there is no denying that the proximate cause is aberrant weather. More often than not, famines are associated with drought events caused by low and/or poorly distributed rainfall.

Human societies have responded to drought in a variety of ways. One response has been to develop agricultural technologies that minimize the impact of drought on crop output. Improvements in germplasm to allow crops to either escape drought or tolerate its yield-reducing effect are an important research thrust. Another response has been to manipulate the crop environment through irrigation, better retention of available soil moisture, and improvement in the plant's ability to better use available moisture. A third type of response has been to improve society's ability to cope with the effect of a production shortfall through better management of the food supply system. This includes maintenance of food stock, transportation of food from surplus to deficit areas, diversification of economic activities, improvements in the capacity of rural institutions to deal with food shortages, and adjustments in macro-economic and sectoral policies to increase income growth.

The main objective of this paper is to document and assess risk-coping mechanisms of farmers in drought-prone areas of Asia. Farmers have, over time, developed a range of strategies to deal with a production shortfall and its impact on welfare. Differences in the characteristics of production systems across environments often reflect these adaptations. The visible symptoms of drought such as widespread hunger, destitution, and death surface when such strategies are inadequate to deal with the magnitude of the problem. It is essential to develop an in-depth understanding of farmers' coping strategies so that technological and institutional interventions that complement such strategies can be developed.

The plan of the paper is as follows. We first briefly discuss the nature of the drought problem in Asian rice systems, followed by an analytical review of studies that have examined farmers' risk-coping mechanisms and their effectiveness. We then assess the economic costs of drought in rainfed rice areas. Based on farm-level data from eastern India, we then provide a detailed account of the various mechanisms used by farmers and assess their effectiveness. Implications of the findings for the design of rice technology and institutional reforms are finally discussed.

Drought: definition and rice area affected

Although drought is commonly understood as a situation in which human welfare is adversely affected due to a shortage of rain, it is not easy to obtain a precise quantitative indicator of drought. The conceptualization of drought varies depending on the perspective taken. Meteorologists generally consider drought as a situation in which rainfall drops by a certain percentage below its long-run normal value. As the effect on crops depends not only on rainfall but also on soil moisture, a refinement of this definition is based on a comparison of potential and actual evapotranspiration. Using a water balance model that takes into account soil properties, drought is also defined as a meteorological situation in which the amount of water required for maximum evapotranspiration exceeds the amount available from rainfall. Although this definition of drought represents an improvement over the simple rainfall-based definition, agricultural drought is said to occur only when economic output from agriculture is reduced as a result of rainfall deficiency. As crops differ in their sensitivities to moisture stress depending on its timing and intensity, meteorological definitions—although useful—are deficient. Even though meteorological drought may be over, indicating a return to normal conditions, the adverse economic effects of drought may persist for several years. To design interventions to deal with drought, it is essential to recognize this difference between meteorological and agricultural drought.

Although famines resulting from prolonged and severe droughts capture public attention worldwide, drought is a regular feature of agriculture in many countries. In arid areas, drought is more or less a permanent feature when irrigation is not available. Even in the humid tropics where annual rainfall is generally sufficient to meet the annual potential evapotranspiration, droughts may occur because of the poor distribution of rainfall over the growing season.

In terms of rice production environment, a minimum of 23 million ha can be characterized as drought-prone in Asia (Table 1). This accounts for about 20% of the total rice area in Asia. More than 50% of this total drought-prone area is located in eastern India. The frequency of drought in India has been well documented. India suffered 36 droughts of varying intensity during 1876-1987 (Table 2). This gives the probability of drought of approximately 32%. Almost 50% of the drought occurrences were widespread and affected more than 30% of the country's area. Based on the rainfall data for 1969-94, the probability of drought in eastern India is estimated to be 35%. Within eastern India, eastern Uttar Pradesh, eastern Madhya Pradesh, and Bihar have experienced a greater frequency of drought than Orissa and West Bengal (Table 3). Although localized droughts can severely reduce the welfare of the people affected, it is the widespread drought that stretches the coping capacity of local institutions and the public sector. Such droughts can result in widespread famine. However, drought is not always the main cause of famine. It is interesting to note that the Bengal famine of 1943-44 was due not to drought but to other factors such as

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

Country	Total rice area[a]		Drought-prone rice area	
	UR	RL	UR[b]	RL[c]
India	6.30	16.0	6.3	7.30
Bangladesh	0.90	6.0	0.9	0.80
Sri Lanka	0.06	0.2	–	na
Nepal	0.10	1.0	0.1	0.27
Myanmar	0.30	2.5	0.3	0.28
Thailand	0.05	8.0	–	3.10
Lao PDR	0.20	0.4	0.2	0.09
Cambodia	–	1.7	–	0.20
Vietnam	0.50	3.0	0.5	0.30
Indonesia	1.10	4.0	1.1	0.14
China	0.60	2.0	0.6	0.50
Philippines	0.07	1.2	–	0.24
Total	10.00	46.0	10.0	13.00

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

Table 2. Years of drought in India.

Year	Area affected (million km²)	% area of the country affected	Category	Ranking
1876	0.49	15.8	Slight	34
1877	2.03	64.7	Calamitous	2
1883	1.03	32.8	Moderate	13
1884	0.70	22.2	Slight	26
1885	0.48	15.4	Slight	35
1891	1.15	36.7	Moderate	9
1896	0.68	21.7	Slight	27
1899	1.99	63.4	Calamitous	3
1901	0.89	28.5	Moderate	20
1902	0.54	17.1	Slight	33
1904	0.98	31.1	Moderate	16
1905	1.09	34.7	Moderate	10
1907	0.85	27.2	Slight	22
1911	0.97	30.8	Moderate	17
1913	0.70	22.3	Slight	25
1915	0.63	20.2	Slight	30
1918	2.16	68.7	Calamitous	1
1920	1.22	38.8	Moderate	8
1925	0.80	25.5	Slight	24
1928	0.67	21.4	Slight	28
1936	0.86	27.6	Slight	21
1941	1.01	32.3	Moderate	15
1951	1.04	33.2	Moderate	11
1952	0.81	25.8	Slight	23
1965	1.35	42.9	Moderate	6
1966	1.01	32.3	Moderate	14
1968	0.45	20.6	Slight	29
1969	0.62	19.9	Slight	31
1971	0.42	13.3	Slight	36
1972	1.39	44.4	Severe	5
1974	0.92	29.3	Moderate	19
1979	1.24	39.4	Moderate	7
1982	1.04	33.1	Moderate	12
1985	0.95	30.1	Moderate	18
1986	0.60	19.0	Slight	32
1987	1.55	49.2	Severe	4

Source: Yojana, June 16-30, 1989, Vol. 33, No. 11, in Fertilizer Association of India (1998).

Table 3. Frequency of deficit rainfall in eastern India.

Meteorological region	Mean rainfall (June-Sept) (mm)	Number of years with actual rainfall less than 80% of mean[a]	Number of years with actual rainfall 80–90% of mean
Eastern Uttar Pradesh	901	5 (1972,77,79,87,92)	3 (1974,86,93)
Eastern Madhya Pradesh	1,137	3 (1974,79,87)	6 (1973,76,81,86,89,91)
Bihar plains	992	4 (1972,82,86,92)	5 (1975,77,79,91,94)
Bihar plateau	1,044	4 (1979,82,86)	3 (1972,73,93)
Orissa	1,084	2 (1974,87)	1 (1979)
West Bengal	1,175	2 (1976,82)	4 (1973,79,89,92)

[a]Deficit rainfall years are given in parentheses.

war and the long-term deterioration in the economic conditions of the poor (Sen 1981).

Rainfed rice covers about 22 million ha in India. This consists of about 16 million ha of rainfed lowland rice and 6 million ha of upland rice. The average rice yield and yield growth rates are lower in eastern India than in Punjab and southern India where irrigated ecosystems predominate (Fig. 1). Because of its rainfed nature, eastern India has a more serious incidence of drought. In addition to drought, the area also suffers from floods and submergence caused by high-intensity rainfall. These abiotic stresses are the major causes of low average yield and high variability of yield in eastern India. Drought has been identified as the single most important constraint to rice production in eastern India (Widawsky and O'Toole 1990), whereas the lack of suitable high-yielding varieties is one of the major reasons for the low productivity of rice in this area (Kshirsagar et al 1997). The productivity growth that has occurred in recent years in eastern Uttar Pradesh and West Bengal is mainly due to the expansion of irrigation, which has reduced the risk of drought.

Some economic consequences of drought

Drought is a major natural hazard that has been historically associated with food shortages of varying intensities, including those that have resulted in major famines. The effect of drought in terms of production losses and consequent human misery is well publicized during years of total crop failure. However, losses to drought of milder intensity, although not so visible, can also be substantial. The effect of drought on human societies can be multidimensional. 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. To ensure the availability of sufficient food, farmers may respond to anticipated drought by making costly adjustments in their production practices. Although farmers may be able to reduce production losses through these adjustments, they have to bear the cost of adjustments. The effectiveness and economic costs of these coping mechanisms vary depend-

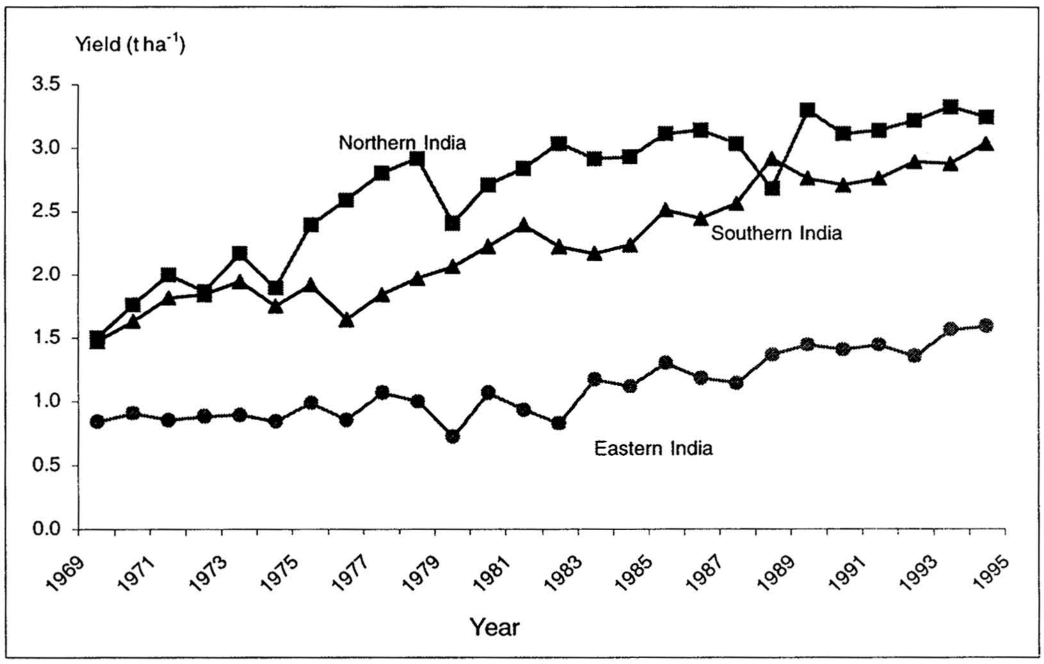

Fig. 1. Trends in rice yield in different regions of India.

ing on the intensity of drought and the nature of the production systems.

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, the decline in agricultural production will set off second-round effects. A decline 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 employment and income in this sector. Similarly, the income of the rural household engaged in providing agricultural inputs will also decline. The reduction in household income will further set off tertiary effects and so on. By the time these ripple effects have played out fully, the overall economic losses from drought may turn out to be much higher than what is indicated by the loss in production of agricultural output alone.

Poor people whose consumption is low may be forced to reduce their consumption further due to a lack of purchasing power resulting from reduced overall income. It is estimated that the proportionate reduction in per capita consumption of the bottom 20% of the income distribution class is ten times that of the top 5% (Mellor 1978). This burden of adjustment may be even more on women and children, who tend to get a lower priority in food allocation within the household. Furthermore, children may be withdrawn from school, thus affecting their long-term production potential. When the effect of drought is so serious that farmers are forced to sell their productive assets such as bullocks, it may take a long time for their future production capacity to be restored even after the meteorological drought has ended. Disease incidence increases during drought years because of poorer nutrition. Severe droughts may lead to destitution and mass migration. The economic and social costs of all these consequences can indeed be tremendous.

Coping mechanisms of farmers

Farmers' risk-coping strategies can be classified into ex ante and ex post depending upon whether they help reduce risk or reduce the impact of risk after the production shortfall has occurred. Because of the lack of efficient market-based mechanisms for diffusing risk, farmers modify their production practices to provide "self-insurance" so that the chances of negative consequences are reduced to an acceptable level. Ex ante strategies help reduce fluctuations in income and are also referred to as income-smoothing strategies. These strategies can be costly, however, 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 through greater flexibility. Diversification is simply captured in the principle of not putting "all eggs in one basket." The risk of income shortfall is reduced by growing several crops that have negatively or weakly correlated returns. This principle is used in different types of diversification common in rural societies. Examples are spatial diversification of farms, diversification of agricultural enterprises, and diversification from farm to nonfarm activities.

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 fertilizers, temporally adjusting input use to crop conditions, and adjusting the area allocated to a crop depending on the climatic conditions. While postponing agricultural decisions until uncertainties are reduced can help lower potential losses, such a strategy can also be costly in terms of income forgone if operations are delayed beyond the optimal biological window.

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

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

Ex ante coping mechanisms

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

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

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

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

Even if the inheritance law may play a large role in determining farm size and the extent of fragmentation, farmers can and do alter their land resource base through land rental markets. Field experience from eastern India indicates that tenants with a given endowment of land types prefer to rent a different land type. Renting better-quality land increases average income. It may also simultaneously achieve the objective of risk reduction.

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

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

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

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

Rainfed rice farmers in eastern India almost invariably grow several varieties for different reasons, including possible risk reduction. In a rainfed rice village in Orissa, more than 70% of the farmers grow 2–5 varieties, with 20% of the farmers growing 6–8 varieties (Kshirsagar et al 1997). Similarly, in the rainfed lowland of Lao PDR, 60% of the farmers grow four or more rice varieties (Pandey and Sanamongkhoun 1998). As with crop diversification, other advantages of varietal diversification are niche matching, staggering labor demand, and generating a range of product characteristics. These latter motives are not directly related to risk management and may condition the extent of varietal diversification practiced by farmers in a given area.

Income diversification. Like crop diversification that uses weak correlation among activity returns to stabilize farm income, diversification of income from farm to nonfarm sources is another way to stabilize income. If fluctuations in nonfarm income are independent of fluctuations in farm output, income diversification through one or more members of the family working in the nonfarm sector can stabilize the total family income. The extent of income diversification may depend on factors such as rural education, transportation infrastructure, access to institutional credit, and availability of local resources for nonfarm activities. These factors may constrain the opportunities for income diversification even when agricultural risk is high. In areas with environmental conditions conducive to a strong agricultural base, income-generating activities that take advantage of agriculture's forward and backward linkages expand. On the other hand, income diversification in agriculturally poor areas tends to be outward-looking, with households diversifying their income geographically (Reardon et al 1988, 1992).

Sharecropping. A large volume of literature on risk and efficiency implications of sharecropping exists (Newbery and Stiglitz 1979, Otsuka et al 1992). Basically, sharecropping arrangements that lead to sharing of input and output also lead to sharing of risk between the landlord and tenant. However, the existence of sharecropping depends on many other factors in addition to risk benefits (Otsuka et al 1992).

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

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

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

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

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

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

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

Ex post coping mechanisms (consumption smoothing)

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

If farmers are able to save during better-than-normal years and use the savings to meet consumption deficits during drought years, they may be able to maintain their consumption level over time despite short-term fluctuations in agricultural output. Savings in agricultural societies may take various forms. They could be held in the form of food grains, cash, and jewelry. They could also be held in the form of productive assets such as bullocks, farm implements, and land. Even if own savings are not enough to meet the consumption deficit, village-level institutions may permit sharing of risk across individuals such that individual consumption fluctuates much less than individual production.

Empirical evidence from several studies in developing countries indicates that consumption smoothing is a common practice among farmers (Townsend 1994, 1995). Based on data from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), crop inventory and cash reserves play major roles in smoothing consumption in the semiarid tropics of India (Lim and Townsend 1994, Paxson and Chaudhuri 1994). The importance of these two mechanisms varied by farm size, with large farmers relying more on crop inventory and small farmers relying more on currency. The use of credit was another important mechanism. Results for Thailand were also similar (Townsend 1995).

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

Based on farm-level data from arid and semiarid areas of India, the decline in cereal consumption in a drought year relative to a normal year varied between 12% and 22% (Jodha 1978). In addition, there were drastic cuts in the expenditure on protective food such as milk, sugar, vegetables, fruits, meat, and others. Such shortfalls in consumption point to the inadequacy of consumption-smoothing mechanisms, especially among small farmers.

Livestock, in addition to being useful for agricultural production, are also an important store of wealth in rural societies. They serve an important role in consumption smoothing. During drought years, livestock are sold and the proceeds used to meet a consumption shortfall. Disposal of livestock can also help reduce carrying costs, which tend to be high, especially during drought years (Kinsey et al 1998). In the Sahel zone of Africa, where poor environmental conditions constrain the efficacy of ex ante mechanisms, manipulation of livestock inventory is an important ex post mechanism (Matlon 1991). Farmers in India similarly use the livestock inventory to reduce a consumption shortfall (Jodha 1978).

A problem with the use of livestock for consumption smoothing is that this coping mechanism, while helping farmers to survive during drought years, can reduce long-term production potential. Where livestock are simply a store of wealth, this will not create a problem. Disposing of livestock in this case would be similar to withdrawing cash from the bank. In fact, the disposal of small animals such as goats and sheep, which tend to be good stores of value, is generally the initial response to income shortfalls. However, livestock are also the major source of draft power needed for several farm operations such as tilling, pumping irrigation water, threshing rice, and hauling farm inputs and outputs. Faced with the prospect of a severe shortage in consumption in a severe or prolonged drought, farmers may sell productive livestock such as cattle, buffalo, and horses. Once these productive livestock assets are depleted, it takes a long time for them to be replenished. Thus, even after the drought is over and rainfall returns to normal, it may take several years for farmers to rebuild their stock of livestock. A typical feature of the livestock depletion-replenishment cycle is that livestock are sold when their prices are falling due to excess supply during drought years (Jodha 1978). Increased demand during the replenishment phase pushes the prices up, making it more difficult for farmers to reacquire livestock. If several drought years occur in a row, the livestock asset may be depleted so severely that several years of normal conditions would be needed for full replenishment. The effect of drought can thus linger on for several years until productive assets are fully replaced. As the mortality of livestock is higher in drought years due to poor nutrition, the asset base can deplete dramatically during a run of drought years. Thus, this coping mechanism could be costly in terms of future production potential forgone. The impact is likely to be greater for small farmers than for large farmers as small farmers often need a longer time to replenish the depleted stock.

As with the depletion of livestock, severe droughts can lead to excessive exploitation of common property resources (CPR) that are a critical component of village livelihood systems (Jodha 1986). CPR are resources owned in common by village residents. These include community forests, pasture/waste land, ponds, river banks and river beds, and groundwater. The poorer segments of the rural population are especially dependent on CPR even in normal times to generate food, fiber, and income. During drought periods, these resources become even more important. For example, the reduced supply of fodder during drought years increases the reliance on forest and community grazing areas for sustaining livestock. Similarly, additional income is generated by selling timber, fuelwood, and other forest products. Collecting edible forest products such as fruits, nuts, and bamboo shoots also increases as farmers attempt to meet the shortfall in production. If these CPR are depleted excessively during drought years, the productivity of agriculture and livelihood of the poor can be adversely affected for many years even after the meteorological drought is over.

Short-term or permanent migration to earn income from cities or far-away places is another coping mechanism. Migration to nearby places is likely to be less effective due to covariate movements in income within a small geographic area. The prospects for earning income within the locality affected by drought are limited due to a reduction in demand for labor in agricultural as well as nonagricultural sectors. Employment in far-away places or in sectors unlikely to be affected by drought will have a stabilizing effect as such income is less covariate with income in drought-affected areas. In addition to seasonal migration during drought periods, diversification of earnings with some family members working permanently in cities helps smooth consumption. A variant of this coping mechanism is the marital relationship with families in far-away places. Income transfers through this mechanism have helped farmers in the semiarid tropics of India to stabilize consumption during drought years (Rosenzweig and Stark 1989). Similarly, diversification of income from the farm to nonfarm sector is a way of exploiting the low covariance for income and consumption stabilization. For example, the proportion of income derived from nonfarm employment outside the region has been higher in the riskier Sahel zone than in the less risky Sudan zone of Africa (Matlon 1991).

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

Despite a poorly developed formal market for credit, the available evidence on the extent of consumption smoothing indicates the presence of informal institutional arrangements for risk sharing in rural areas. These may be village-level rice banks, local money lenders, mutual self-help groups, interlocked credit and labor markets, and social and family networks. Income transfers (in cash or kind) through these informal arrangements can provide very effective insurance, especially if the risk affects only a few households (Jodha 1978, Ben-Porath 1980, Platteau 1991, Fafchamps 1992, Townsend 1995). The provision of such insurance is believed to be one of the critical functions of the family as an institution (Rosenzweig 1988). Although very effective in insuring poor households against a consumption shortfall due to life-cycle events such as death or illness in the family, these mechanisms are less effective in dealing with covariate risks that affect everybody within the community. Historical records of mass migration, starvation, and death attest to the failure of these informal mechanisms when droughts are severe and widespread. These informal arrangements that characterize traditional rural societies also seem to weaken considerably in the face of commercialization and greater exposure to the outside world (Jodha 1978).

Publicly sponsored relief programs are used to deal with the failure of these ex post consumption-smoothing mechanisms in the face of large covariate risk. To the extent that food insecurity is due to the lack of exchange entitlements, these relief programs are designed to transfer income to farmers in affected areas to reduce consumption deficits and prevent excessive asset depletion. The relief programs generally take the form of income transfer/employment generation although direct food distribution may also be a component when drought is severe. Several authors (Corbett 1988, Hay 1988, Dev 1996) have discussed the strengths and weaknesses of various types of relief programs.

Estimating the economic cost of drought in eastern India

Given the multidimensional nature of the effect of drought, assessing its economic cost will require detailed studies of the production system, labor market, and overall economic structure of the location, including economic linkages with the wider economy. Such a comprehensive assessment is clearly beyond the scope of this paper. Here we attempt to illustrate the estimation of some of the relatively easily quantifiable costs using a case-study approach. Data constraints limit the focus of this estimation to two states of eastern India: Orissa and eastern Uttar Pradesh. The estimation of production losses is based on aggregate data from Orissa, whereas the nature of coping mechanisms is illustrated using farm-household data from both states.

Characteristics of the rice production system in Orissa and eastern Uttar Pradesh

Rice occupies approximately 4.5 million ha in Orissa. Figure 2 shows the trends in area, yield, and output in Orissa. From 1969 to 1994, the production growth rate was approximately 2.2% per year. As the growth rate in area was almost nil, yield growth has been the main source of production growth. The coefficients of variation estimated after correcting for the linear trend effect were 16.9%, 3.9%, and 14.5% for production, area, and yield, respectively. The coefficient of variation for area was the least, with most of the production variation being accounted for by variation in yield.

A major feature of agriculture in Orissa is the rapid expansion of area under pulses and oilseeds. In the rabi (postrainy) season, these two crop categories account for most of the area. Intensification of land use in Orissa has occurred mainly as a result of the expansion of area under these two crop categories. The importance of these crops is less in districts that are less drought-prone and more irrigated as rice would be the preferred crop. This is especially true in the kharif (rainy) season, in which rice is the dominant crop. In the rabi season, pulses and oilseeds are the major crops. Crop intensification through the expansion of pulses and oilseeds has contributed in a major way to raising the income of Orissa farmers.

Based on data from the Revenue Department of Orissa, the state experienced drought of varying intensities in seven years (1974, 1976, 1979, 1982, 1984, 1987, 1996) out of the past 28 years (1970-97). The probability of severe

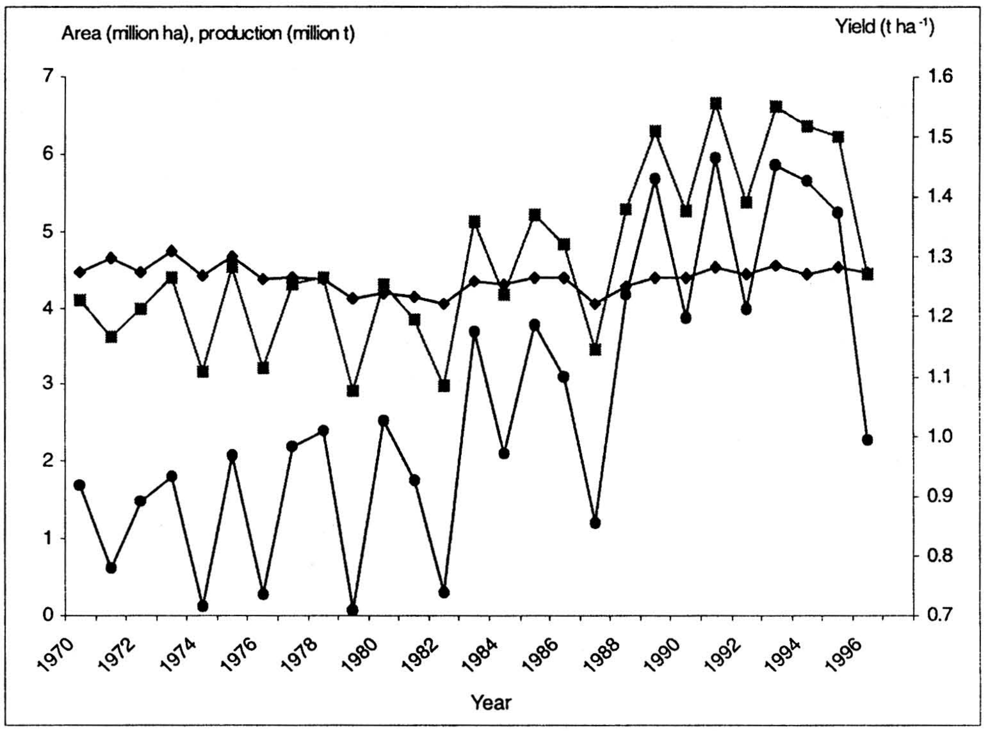

Fig. 2. Trends in area (◆), production (■), and yield (●) of rice in Orissa, 1970-96.

drought in Orissa is, hence, 0.25. Of these seven years, drought was more severe in 1974, 1976, 1979, 1987, and 1996. These droughts were quite widespread. According to the estimates from the Revenue Department, 56% of the total of 51,536 villages were drought-affected in 1996. The total rainfall during these years was less than 75% of the long-term normal rainfall (Fig. 3). Based on the total rainfall figures, the droughts of 1982 and 1984 appear to have been relatively milder, but a poor distribution of rain created local droughts.

Losses in rice production were high in all drought years except 1984. In 1979, 1982, and 1987, production losses were as high as 30% of the trend value. The drought of 1996 reduced output by 25% of the trend value. Even the milder drought of 1984 reduced output by nearly 12% of the trend value. Most of the production loss was caused by a reduction in yield. The loss in area sown contributed to a smaller proportion of output loss. This is expected as farmers can adjust area sown only in response to early season drought. If drought occurs mid-season or toward the end of the season, farmers may reduce the area harvested, but this reduction is not captured in the official data. Production losses in such situations result almost entirely from the loss in yield. In fact, the analysis of rainfall data for Orissa indicates that low rainfall in September/October is the major reason for the yield-reducing effect of drought. In September/October, rice planted in June is close to anthesis, which is a very drought-sensitive period of growth.

In eastern Uttar Pradesh, approximately 2.9 million ha are planted to rice. The average yield of rice[1] for 1992-94 was 1.7 t ha^{-1}. The growth rate in rice yield in eastern Uttar Pradesh during 1982-94 was 4.92% per year. Of the five states in eastern India, Uttar Pradesh experienced the highest yield growth rate during the period. Rapid expansion of tubewell irrigation, expansion of area under high-yielding varieties, and better infrastructure are believed to be the major reasons for the state's impressive performance.

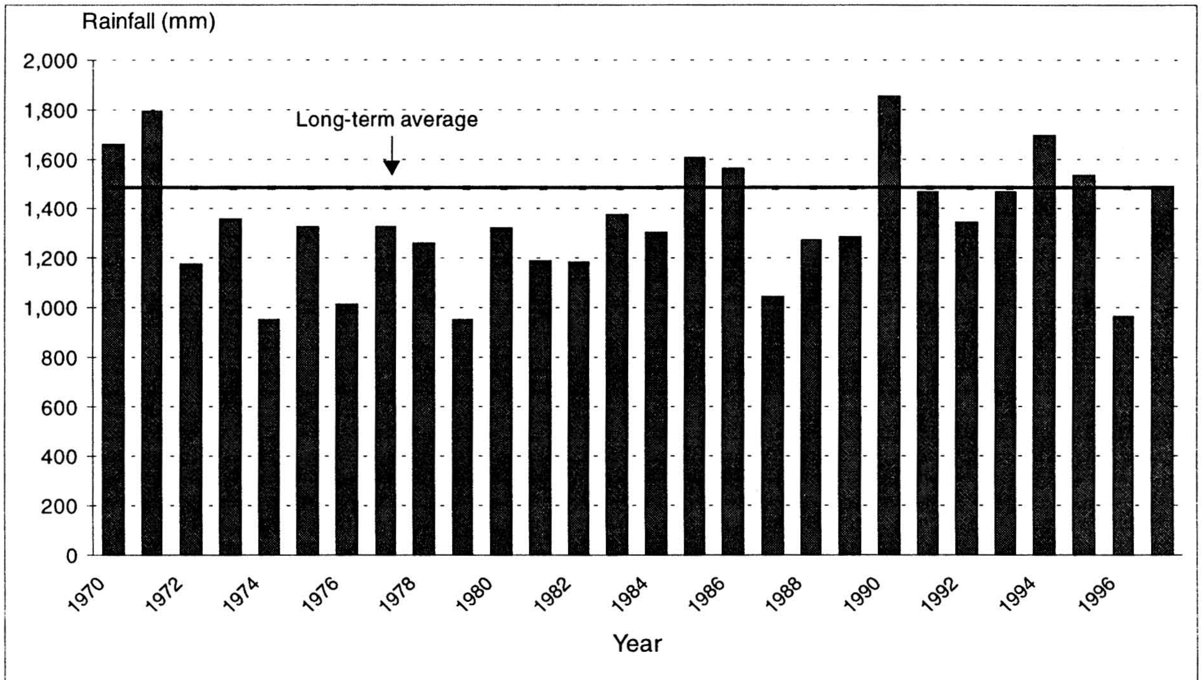

Fig. 3. Normal and actual annual rainfall for Orissa, 1970-97.

[1]Following the Indian data-reporting system, yields are expressed in this paper in terms of milled rice, not paddy rice. The conversion factor used was 1 kg paddy rice = 0.66 kg milled rice.

Between 1969 and 1994, Uttar Pradesh experienced eight droughts of varying intensities (Table 3).

Production losses to drought

Ideally, the assessment of the impact of drought on production losses could be carried out using an aggregate production function, with a suitable index of drought as one of the independent variables. As yield is dependent on the seasonal pattern of rainfall, the index of drought would need to capture the effect of the timing and quantity of rainfall throughout the crop growth period. The index of drought that is biologically meaningful will require the simultaneous consideration of moisture availability to the crop and sensitivity to moisture deficit at different growth stages. Moisture availability to a crop is a function not only of rainfall but also of soil and topographical characteristics. Similarly, sensitivity to moisture stress depends on the type of varieties grown and management practices used. A precise measurement of the effect of drought on yield would thus require a large number of parameters describing soil, plant, and moisture relationships and would be more meaningful only within a homogeneous production environment. As the objective in our study is to measure impact at the district and state level, a simpler approach to the measurement of drought impact is needed. As a first approximation, we have simply used trend analysis with dummy intercept variables specified for each of the years known to have experienced severe drought. Information on the incidence of drought was obtained from government publications. This method provides a lower-bound estimate of production losses as losses to less severe droughts are ignored. Also, farmers may have incurred some costs, through changes in management practices such as the extra cost of pumping water, to reduce yield losses. Such economic costs are ignored in this aggregate analysis. The coefficient of the drought dummy variable provides a measure of the average production losses during drought years, while that of the time trend captures the trend effect on the data.

Based on the dummy variable model (Table 4), the average production loss in Orissa in drought years is estimated to be 1.5 million t, which is about 33% of the average annual output of rice. At the price of \$150 t^{-1}, the value of output lost in drought years is thus \$225 million[2]. Such a massive production loss in drought years is bound to affect the welfare of rice farmers and consumers dramatically. To estimate the average annual loss to drought, the figure obtained above needs to be weighted by the probability of occurrence of drought. Using the probability of 0.25, the average annual loss to drought is 0.38 million t. This is equal to about 8% of the mean rice output of the state (mean output of 4.7 million t). The value of this loss is \$57 million per year.

Depending on the nature of the drought, the production of other crops may also be affected. This effect can occur in both rainy-season crops and dry-season crops that are grown using residual soil moisture. Drought that depletes the soil moisture below the level necessary for dry-season crops will affect their production. Both the area and yield of these crops are likely to decline.

Table 4. Regression estimates of production losses to drought for various crops in Orissa (1970-96).

Parameter	Rice	Pulses	Oilseeds
Dependent variable	Production (000 t)	Production (000 t)	Production (000 t)
Intercept	3,711[a] (19.63)	490 (7.96)	194.6 (4.0)
Time	93 (8.74)	25.6 (7.71)	27.6 (9.75)
Drought dummy[b]	–1,498 (–7.50)	–210 (–3.15)	–107 (–2.04)
R^2	0.83	0.71	0.78
Observations (no.)	28	28	28

[a]Numbers in parentheses are the t-values.
[b]The coefficient of drought dummy provides an estimate of the production loss during drought years.

[2] Based on the milled rice price of Rs 6 kg^{-1} and using the exchange rate of US\$1= Rs 40.

Major nonrice crops in Orissa are pulses and oilseeds. These crops are grown in both the rabi and kharif seasons. An analysis of data for 1970-96 indicates that production losses are greater in the rabi than in the kharif crops in drought years. A greater loss in the rabi season, especially for pulses, could be due to the predominance of pulses in the rabi season when they are grown mainly using residual soil moisture. Due to their deeper roots, oilseeds are less likely to suffer from drought than pulses, which are shallow-rooted. In addition, oilseeds are generally grown in areas with supplemental irrigation.

Based on a regression analysis with dummy variables for the seven drought years and the time trend as explanatory variables, the average losses in the production of pulses and oilseeds in drought years are estimated to be 0.21 million t and 0.11 million t, respectively (Table 4). Using the value of \$300 t^{-1} for pulses and \$375 t^{-1} for oilseeds, the total production loss in drought years is estimated to be \$104 million. As the probability of drought is 25%, the expected value of the production loss per year is thus \$26 million. The total value of the annual production loss (rice, pulses, and oilseeds) is thus \$83 million.

Other minor cereals such as maize and millet grown during the kharif season are also likely to be adversely affected by drought. As the total value of these minor cereals is small in comparison with rice, pulses, and oilseeds, we have not attempted to estimate the loss in value of minor cereals.

Effect on employment

Assuming that the employment elasticity of rice output is 0.6 (Bhalla 1987), a 10% reduction in output will lead to a 6% reduction in employment. The average output reduction of 33% during a drought year will thus reduce employment in rice production by 20%. Assuming that rice requires 120 person-days ha^{-1}, the total employment in rice production in Orissa in normal years is approximately 540 million person-days. The loss in employment in rice production will thus be about 110 million person-days. If the losses in employment in the production of pulses and lentils are also added, the total loss of employment in agricultural production may be on the order of 150 million person-days. The second-round effects of such a massive loss in employment and earning opportunities will certainly be quite large. If 75% of the farm households belong to small and marginal categories and may be in need of drought relief, the public relief program will need to generate almost 110 million person-days of employment in drought years. At the wage rate of \$1 per person-day, additional employment will cost \$110 million[3].

Analysis of drought-coping mechanisms of farmers in eastern India

To examine the drought-coping mechanisms of farmers, we conducted a field survey of 60 farmers in Faizabad District, eastern Uttar Pradesh, and 60 farmers in Orissa selected from six drought-prone districts. The panel data for the period 1994-97 from two villages of Faizabad were used to examine ex ante risk-coping mechanisms. The data from Orissa were used to assess ex post coping strategies.

The analysis of ex ante coping strategies is based on farm-level panel data for 1994-97 from two villages of Faizabad: Mungeshpur and Itgaon. The rice production systems of these two villages differ in several aspects, with the major difference being in access to irrigation, which is greater in Mungeshpur. A total of 30 farmers from each village were selected using a stratified random sampling method.

Table 5 summarizes the major characteristics of the study villages. The average operational holding is 50% lower in Mungeshpur than in Itgaon. Farmers in Itgaon also have proportionately more upland area where soils are lighter and water drains out relatively faster.

[3] It should be noted that, while the loss in employment will have financial consequences for the people affected, the addition of the monetary value of employment lost in crop production to the value of crop loss will lead to double counting as the cost of labor, which is an input to agricultural production, is already captured in the value of output.

Table 5. General characteristics of the study villages, Faizabad, eastern Uttar Pradesh.

Characteristics	Mungeshpur				Itgaon			
	Small farmers[a]	Medium farmers[b]	Large farmers[c]	Overall	Small farmers	Medium farmers	Large farmers	Overall
Irrigated area (%)	93	74	75	85	34	35	39	37
Average operational holding (ha)	0.5	1.5	2.2	0.7	0.5	1.4	2.9	1.4
Proportion of land type (%)								
Upland	38	44	24	34	59	60	48	55
Medium land	6	16	43	14	15	21	34	24
Lowland	57	40	33	52	26	20	18	21
Average years of schooling of household head	5	8	12	5	3	8	9	6
Average household size (members)	7	9	7	7	7	8	9	8

[a]Small farmers are those farmers with total landholding of less than 1 ha.
[b]Medium farmers are those with total landholding of 1 to 2 ha.
[c]Large farmers are those with total landholding of more than 2 ha.

Rice grown in these fields is relatively more drought-prone than that in bottom lands where drainage water accumulates. In Mungeshpur, nearly 85% of the fields have access to irrigation, whereas in Itgaon 37% of the area is irrigated. In addition, the reliability of irrigation differs between these two villages. Private tubewells are more common in Mungeshpur than in Itgaon, where relatively less reliable public tubewells are the major sources of irrigation.

Figure 4 presents rainfall data from a monitoring station close to the surveyed villages for 1994-97. Compared with 1994 and 1997, rainfall in June and July was much lower in 1995 and 1996. Judging by the distribution and amount of rainfall, 1994 may be classified as a "normal" year, 1995 and 1996 as drought years, with drought being more severe in 1995, and 1997 as a "good" year. The delay in the start of the monsoon reduced the early season rainfall in 1995 more than in 1996. Between the two villages, the rice production environment is "riskier" in Itgaon than in Mungeshpur as shown by a low mean and a high coefficient of variation of rice yield and returns in Itgaon (Table 6).

The sampling design used to select farm households in Orissa was stratified and purposive. In the first stage, six districts were selected on the basis of crop loss estimates, provided by the Revenue Department, for drought year 1996. The districts selected were Balasore, Khurda, Kalahandi, Mayurbanj, Nawapara, and Bolangir. Production losses to drought in these districts were more than 70%. In the second stage, two blocks from each district were selected at random from among the list of blocks that were severely affected. Finally, in the third stage, two villages from each block were randomly selected from the list of villages where the reported crop loss was more than 75%. Five farmers from each village were selected for a detailed interview. Of the five farmers, two were marginal (with less than 1 ha of land), two were small (between 1 and 2 ha), and one was large (with more than 2 ha). Information was collected using a structured interview questionnaire. As this was a one-shot survey, farmers' responses to the 1996 drought were elicited by asking them to compare various aspects of the household economy for 1996 with those of 1995, which was a normal year.

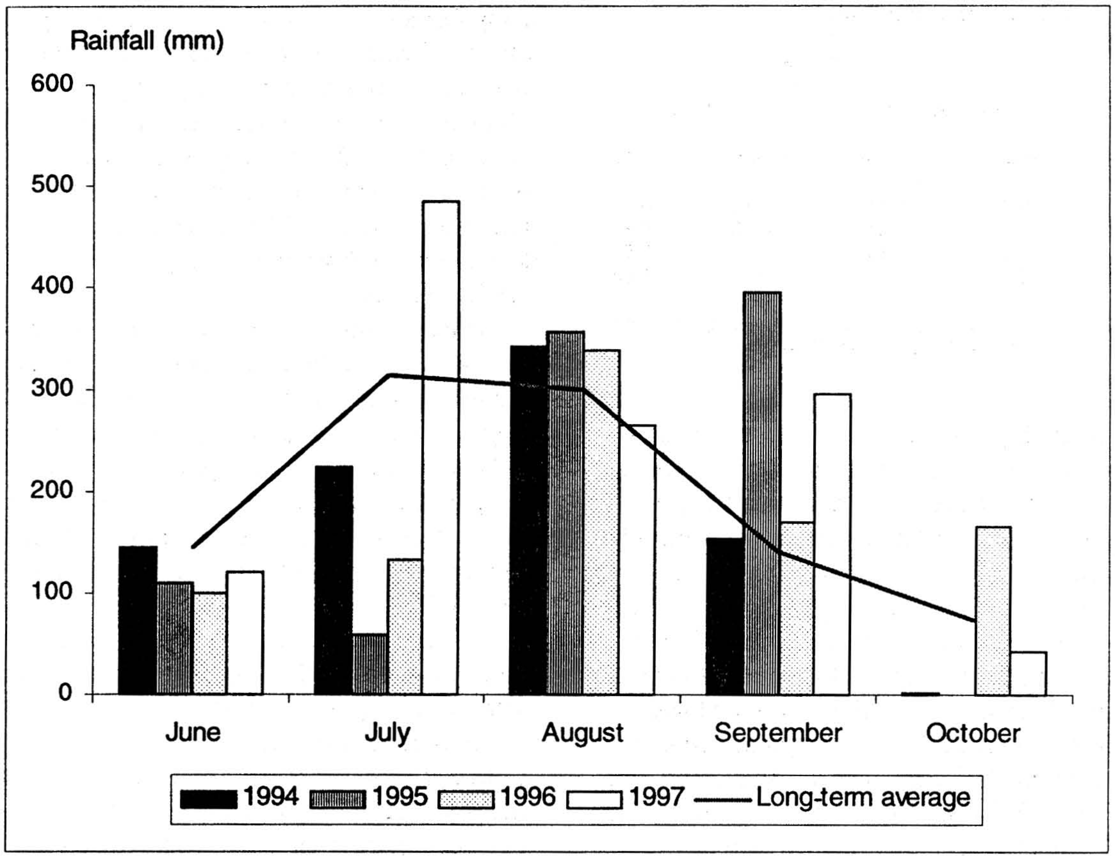

Fig. 4. Kharif-season rainfall for Masodha, eastern Uttar Pradesh, 1994-97.

Table 6. Measures of probability distribution of plot-level rice yield, net returns, and gross returns of rice (1994-97), Faizabad, eastern Uttar Pradesh.

Item	Mungeshpur	Itgaon
Yield		
Mean (kg ha^{-1})	1,432	1,077
CV[a] (%)	58	65
Skewness	3.27	1.01
Gross returns		
Mean (Rs ha^{-1})	6,610	4,409
CV[a] (%)	67	67
Skewness	4.72	1.03
Net returns		
Mean (Rs ha^{-1})	5,253	3,250
CV[a] (%)	84	97
Skewness	3.97	0.99

[a]CV = coefficient of variation.

Ex ante coping mechanisms

There is no clear evidence that a greater degree of land fragmentation in Itgaon is a risk-reducing strategy. Instead, this appears to be a function mainly of farm size, which is larger in Itgaon. The degree of crop diversification, as judged by the Simpson Diversification Index (Walker and Ryan 1990), was higher in Itgaon in both the rainy and postrainy seasons than in Mungeshpur (Table 7). In Itgaon, farmers grew rice in a proportionately smaller area than in Mungeshpur and relied more on pulses and maize, which grow well under rainfed conditions. Mixed cropping and intercropping were also more common in this village. The average number of intercrops over the four years in the kharif season in Itgaon was 19, whereas the corresponding number for Mungeshpur was only 11. The crop diversification index in the kharif season in Itgaon was higher in the unfavorable years of 1995 and 1996 than in 1994 and 1997. Farmers may have used a greater degree of crop diversification to reduce risk in the years that were less favorable to rice.

As with land fragmentation, crop diversification may occur for several reasons in addition to risk reduction (Smale et al 1994). Differences

Table 7. Crop diversification index[a].

Year	Villages			
	Mungeshpur		Itgaon	
	Kharif	Rabi	Kharif	Rabi
1994	0.47	0.56	0.72	0.71
1995	0.53	0.55	0.90	0.77
1996	0.58	0.57	0.82	0.67
1997	0.50	0.53	0.75	0.68

[a]The diversification index ranges between zero and unity, with higher values indicating a greater degree of diversification.

in land quality can lead to crop diversification even if yields are deterministic. For crop diversification to be effective for risk reduction, the temporal yield correlation among crops must be low. Because of the statistical difficulty in estimating yield correlation precisely when the area under individual crops is very small, we have examined the temporal stability of farm income. This analysis will be presented later.

In both Mungeshpur and Itgaon, rice area decreased in 1995 and 1996 in comparison with 1994 and 1997 (Table 8). The contraction in rice area in Itgaon was much sharper than in Mungeshpur. Delayed rainfall in 1995 forced many farmers in Itgaon to forgo rice completely, whereas farmers in Mungeshpur were able to maintain the rice area by using irrigation. Although some of the rice area was diverted to less moisture-sensitive crops such as pulses, maize, and various intercrops, most of the rice land was left fallow. The area under fallow declined in 1996 when the early season drought was less severe.

Transplanting was by far the most dominant method of crop establishment in Mungeshpur (Table 9). The availability of supplemental irrigation made transplanting in more than 75% of the area feasible in Mungeshpur even in drought years such as 1995 and 1996. In Itgaon, however, even in the most favorable rainfall conditions of 1997, the area transplanted was only 54%.

As seasonal conditions vary from year to year, farmers may also adjust crop establishment methods in response. A farmer who transplanted all rice fields in one year may choose to use dry seeding the following year. Similarly, a farmer who dry-seeded in one year may subsequently wet-seed a part of the area and transplant the other part the following year. In addition to

Table 8. Cropping pattern, Faizabad, eastern Uttar Pradesh.

Cropping pattern	Mungeshpur					Itgaon				
	1994	1995	1996	1997	All years	1994	1995	1996	1997	All years
	(% of area)									
Kharif										
Fallow	17	20	15	16	17	33	48	33	27	35
Rice	60	53	54	59	56	32	10	24	35	26
Fodder	7	4	6	6	6	7	5	6	5	6
Sugarcane	6	13	10	8	9	2	7	5	3	4
Maize	2	2	4	3	3	6	7	8	10	8
Others[a]	7	8	11	8	9	19	22	24	21	22
Rabi										
Fallow	12	8	9	15	11	18	22	24	18	21
Wheat + oilseeds	58	52	56	60	57	40	41	46	46	44
Pulses + oilseeds	11	11	9	8	9	22	17	17	15	18
Sugarcane	8	14	9	1	7	2	6	0	2	3
Vegetables	3	2	7	5	5	5	5	4	5	5
Pulses	0	2	6	5	4	4	5	7	8	6
Others[b]	7	10	4	6	6	8	4	2	5	5
Zaid										
Fallow	80	77	82	99	86	97	92	100	100	97
Pulses	8	7	7	0	5	1	1	0	0	0
Sugarcane	8	13	9	0	7	2	7	0	0	2
Others[c]	5	2	2	1	2	0	1	0	0	0

[a]Includes sweet potato, cereal and pulses, pigeonpea, and mixed cereals.
[b]Includes pulses, fodder, vegetables, oilseeds, and vegetables + oilseeds.
[c]Includes vegetables, fodder, pulse + oilseed, and cereal + oilseeds.

Table 9. Percent area by different methods of crop establishment, Faizabad, eastern Uttar Pradesh.

Rice[a]	Mungeshpur				Itgaon			
	1994	1995	1996	1997	1994	1995	1996	1997
	(% area)							
DS	5	2	5	0	18	55	40	3
TP	78	76	86	88	27	39	50	54
WS	17	22	9	12	55	7	10	43

[a]DS = dry-seeded rice, TP = transplanted rice, WS = wet-seeded rice.

seasonal conditions, variations in other factors such as labor supply, working capital, and pest problems may also affect the choice of crop establishment method. Temporal variations in each of these crop establishment methods were higher in Itgaon than in Mungeshpur. Nearly 20% of the farmers in Mungeshpur transplanted all of their fields in all four years. In contrast, none of the farmers in Itgaon maintained the same method of crop establishment in a field over time.

Farmers often use more than one method of crop establishment within a season for a variety of reasons such as risk reduction, staggering of labor demand, and better matching with field conditions. In Mungeshpur, more than 60% of the farmers practiced only one method in each year (Table 10). The remaining used a combination of methods, with transplanting being the dominant method. A relatively favorable environmental condition in Mungeshpur probably led to the dominance of the use of the single most-profitable method. In contrast, a combination of methods was more common in Itgaon.

In Mungeshpur, more than 90% of the total rice area was planted to modern varieties. The adoption of modern varieties in Itgaon was lower and varied between 54% and 67% (Table 11). Short-duration varieties occupied proportionately more area in Itgaon than in Mungeshpur. The lower rate of adoption of modern varieties and a greater importance of short-duration varieties were probably adaptations to the more moisture-deficient environment in Itgaon.

In addition to variations in crop establishment methods, temporal variations in the proportion of area under modern varieties were

Table 10. Percentage of rice farmers using different methods of crop establishment, Faizabad, eastern Uttar Pradesh.

Method[a]	Year			
	1994	1995	1996	1997
	(% of farmers)			
Mungeshpur				
TP only	57	54	67	57
WS only	3	13	3	0
DS only	0	3	3	3
TP + WS	10	27	20	40
TP + DS	3	0	3	0
WS + DS	0	3	4	0
TP + WS + DS	7	0	0	0
Itgaon				
TP only	13	23	31	14
WS only	13	6	0	29
DS only	7	53	42	0
TP + WS	30	0	8	50
TP + DS	3	0	8	4
WS + DS	34	18	8	3
TP + WS + DS	0	0	3	0

[a]TP = transplanting, WS = wet seeding, DS = dry seeding.

also higher in Itgaon. The proportionate area under modern varieties decreased in less favorable years (1995 and 1996) as farmers relied more on traditional varieties. Thus, an important coping mechanism appears to be a reliance on traditional varieties in years characterized by planting-season drought.

To the extent that yields of different rice varieties are poorly correlated, overall risk can be reduced by growing several rice varieties. The varietal diversity index for both villages averaged 0.85, indicating that diversification into several varieties as a way of reducing risk was more important in Mungeshpur.

The effect of crop diversification on the stability of kharif-crop income was examined by

Table 11. Percentage area by variety, Faizabad, eastern Uttar Pradesh.

Varieties	Mungeshpur 1994	1995	1996	1997	Itgaon 1994	1995	1996	1997
	(% area)							
Type								
Modern	89	93	94	91	67	64	54	61
Traditional	11	7	6	9	33	36	46	39
Duration[a]								
Short	26	25	29	31	60	66	55	66
Medium	27	24	43	55	22	17	36	32
Long	46	51	28	14	18	16	9	2

[a]Short = ≤ 120 days, 120 days < medium ≤ 135 days, long = > 135 days.

comparing the coefficient of variation (CV) of rice and the CV of kharif-crop income. The stabilizing effect for Itgaon is shown by a lower CV of all-crop income (11%) relative to that of kharif-crop income (55%). Most of the points are below the 1:1 line, thus indicating the stabilizing effect of rabi-season crops on kharif income (Fig. 5). This stabilizing effect was lower in Mungeshpur.

Ex post coping mechanisms

Based on the analysis of farm-level data from five districts of Orissa[4], Table 12 presents a decline in production of four major categories of food crops during drought years. Compared with production in normal years, rice production declined by as much as 98% in drought years. As production of all other crop categories also declined in drought years, the total availability of food in drought years was substantially lower than in normal years.

Table 13 presents income[5] by sources for normal and drought years. Both crop income and income from farm labor declined dramatically during drought years. A decline in crop income is a measure of the reduction in agricultural output due to drought. In addition to this loss, households that provide farm labor suffer a loss of income as the demand for labor also shrinks during the drought year. While the income from crops declined by 65%, the income from farm labor declined by 50%.

With such a dramatic decline in farm income, farmers in these villages would have to rely on nonfarm labor and asset sales to prevent a drastic fall in consumption. In fact, income from nonfarm labor increased in all districts. The nonfarm income was generated mostly through the migration of male family members to distant places to work mainly as construction and industrial labor. Migration to far-away places was necessary as additional nonfarm employment in the local area was not available due to low demand for labor in the agro-processing sector that was also adversely affected by drought. Among the farmers surveyed, nonfarm income increased by 55%.

However, the rise in nonfarm income was insufficient to compensate for the loss in farm income. Even after accounting for additional nonfarm income, the total income in a drought year was only 55% of the normal-year income. As a result, farmers fell back on asset sales. The major assets sold were land, livestock, and jewelry. Bullocks and cows were the major types of livestock sold. For the sample of farmers surveyed, nearly 55% sold bullocks (Table 14). These were sold in distant markets and fetched a

[4] For Table 12 only, the analysis covered five districts. In other tables, six districts are considered.

[5] Here crop income is defined as the gross value of agricultural output. Although value added in agricultural production (gross value of output minus the cost of inputs) would have been a better measure of income, the lack of input data prevented us from calculating the value added. In any case, the cost of purchased inputs is only a small proportion of the total cost of production in these rainfed environments where family labor is the major input.

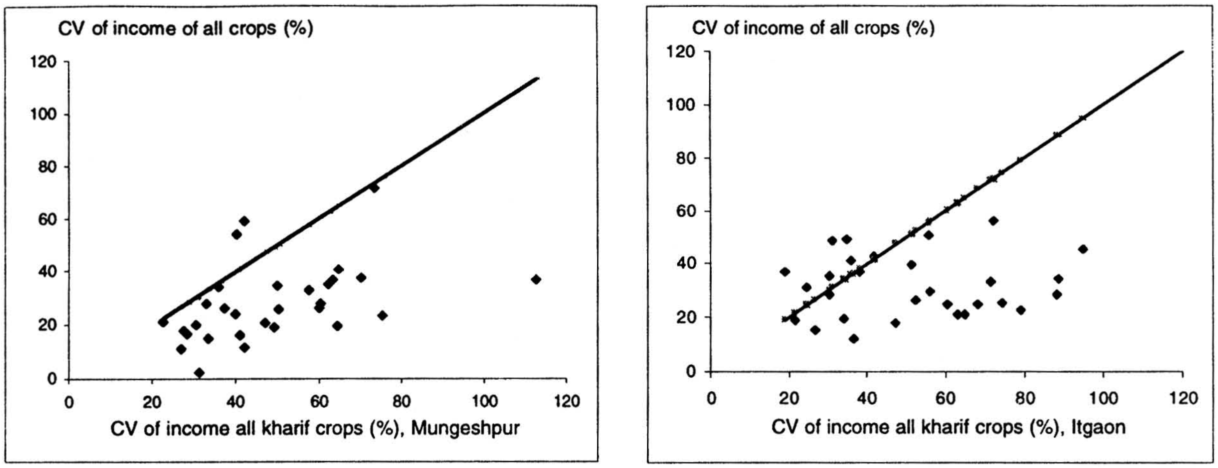

Fig. 5. Relationship between the coefficient of variation (CV) of income from all crops and the CV of income of kharif crops, eastern Uttar Pradesh.

Table 12. Estimates of production of major food grains in normal (1995) and drought (1996) years.

District	Normal year production (kg household^{-1})				Drought year production (kg household^{-1})				Percentage difference			
	Rice	Pulses	Oilseeds	Vegetables	Rice	Pulses	Oilseeds	Vegetables	Rice	Pulses	Oilseeds	Vegetables
Balasore	2,793			160	220			120	–92			–25
Bolangir	1,918	116	18	364	41			227	–98	–100	–100	–38
Khurda	1,712	29	10	461	559	2		77	–67	–93	–100	–83
Mayurbanj	1,548				295				–81			
Nawapara	1,647	187	20	420	413	8	3	340	–75	–96	–85	–19
All districts	1,911	65	10	292	314	2	0.46	150	–84	–97	–95	–49

Table 13. Average income per household in Orissa during normal and drought years.

Source	Normal year (Rs)	Drought year (Rs)	Difference (%)
Crop	12,018	4,210	–65
Rice	9,290	2,367	–74
Other crops[a]	2,728	1,890	–31
Farm-labor	2,474	1,182	–52
Nonfarm activities	4,291	6,661	55
Other sources[b]	1,317	1,192	–9
Total income	32,118	17,502	–46
Sale of livestock	72	1,774	A[d]
Sale of land	0	4,768	A[d]
Sale of other assets[a]	0	2,329	A[d]
Mortgaging/borrowing	0	3,130	A[d]
Total (asset sale + borrowing)	72	12,001	A[d]

[a]Other crops include vegetables, oilseeds, pulses, and other cereals. [b]These include plucking of leaves, *sal* and *sabai* plants, and fruit sales.
[c]Other assets include farm implements, utensils, jewelry, timber, trees, and bamboo.
[d]The percentage difference was not calculated because the values for the normal year were zero or close to zero.

Table 14. Percentage of household engaged in selling of animals, implements, and other assets.

Item	Balasore	Bolangir	Kalahandi	Khurda	Mayurbanj	Nawapara	All districts
Selling of animals							
Bullock	80	73	18	77	30	40	55
Buffalo		9					2
Calf	10				10	10	5
Chicken	20	9		8			6
Cow	50	45	18	15	10	10	25
Goat	10		9		30	10	9
Selling of assets							
Bullcart			9	62	10		16
Jewelry	10	45		46	0	40	25
Land	80	36	18	31	20	20	34
Tree	60			54	60		30
Utensils		9		38	10		11
Mortgaging of assets							
Jewelry	20	0		15	0	10	8
Land		73		31	30	10	25
Ave. time elapsed before reacquisition of assets sold (mo)	13	12	13	15.3		14.5	14.2
% who have not yet reacquired assets sold	60	73	20	15	50	40	42

lower price because of excess supply and poor health. Farmers identified the inability to reacquire bullocks sold during drought years as one of the constraints to increased production in the succeeding year.

In addition to the sale of bullocks, farmers also sold their land to meet consumption needs. In a land-constrained agricultural economy, the sale of land is an indicator of desperation. Selling of land was reported by 34% of the farmers. In addition, 25% mortgaged their land. Mortgaging is often a first step that leads ultimately to the complete loss of land. Small farmers are unlikely to be able to reacquire land lost through sale. The pauperizing effect of land loss in a society characterized by a highly skewed distribution of assets and income is a major effect of severe drought. Loss of land makes these poor farmers more vulnerable to future income shocks as their capacity of smooth consumption through this mechanism is reduced. Such farmers are likely to end up with not only lower income but also more variable consumption. Thus, the loss of this consumption-smoothing mechanism will further reinforce their poverty. The survey data indicated that the average time elapsed for reacquiring sold assets was 14 months. About 42% of the farmers were unable to reacquire their assets even after two years. Obviously, the delay is likely to be longer for the relatively poorer farmers.

A strategy for dealing with a shortage in food-grain production is to rely on the market to meet the deficit. The purchase of food grains during the drought year increased in comparison with the corresponding values in normal years (Table 15). The quantity of purchased rice increased by 226%. The increase in purchased wheat in areas where rice is the preferred food grain indicates that farmers substituted wheat for rice when the shortage of rice was widespread. However, even after considering purchases of rice, the total availability of rice declined by 41%. The total availability for large farmers declined even more than for small farmers. As large farmers are likely to have been net sellers during normal years, this decline in availability for large farmers probably reduced the sale of rice more than its consumption. Assuming that consumption equals total availability in the case

Table 15. Production, purchase, and consumption of major food crops in Orissa.

Food crop	Normal year[a] (kg capita⁻¹)	Drought year[a] (kg capita⁻¹)	Difference (%)
Rice			
Self-produced	340	80	–77.9
Purchased	50	150	226.0
Total consumption	390	230	–40.5
Wheat			
Self-produced	2	2	–22.2
Purchased	6	15	169.2
Total consumption	8	17	120.0
Vegetables			
Self-produced	63	31	–50.7
Purchased	2	1	–14.3
Total consumption	65	32	–49.8
Others[b]			
Self-produced	22	10	–55.4
Purchased	2	5	242.9
Total consumption	24	15	–36.7

[a]Normal years and drought years are 1995 and 1996, respectively.
[b]Includes minor millets, pulses, and oilseeds.

of small farmers, the reduction in their consumption is on the order of 20%. This large reduction in consumption can adversely affect their health. Women and children are likely to suffer more as they generally receive lower priority in food allocation than men.

Table 16 summarizes the nature of adjustments in consumption during drought years. Households reduced the number of meals taken per day (67%) as well as the quantity consumed per meal (88%). The average number of meals consumed during normal years (3 per day) declined to 2.3 per day in drought years. In most cases, women skipped one meal. In addition, their quantity consumed per meal also declined. Again, the burden of this fell mostly on women. Some farmers (both men and women) mentioned that, during drought years, they cooked only once a day and skipped the meal whenever the cooked food ran out.

Table 16. Nature of consumption adjustments in selected districts of Orissa.

Item	Balasore	Bolangir	Kalahandi	Khurda	Mayurbanj	Nawapara	All districts
% of households that reduced quantity of food consumed	70	100	70	100	90	90	87.5
Ave. no. of meals during normal year	3.0	3.1	2.8	3.0	3.4	3.2	3.1
Ave. no of meals during drought years	2.6	2.0	2.5	2.1	2.0	2.4	2.3
% of households that reduced no. of meals	50	100	30	77	70	70	67
Ave. no. of meals during drought year (those with reduction in no. of meals)	1.2	1.2	1.0	1.3	1.6	1.3	1.3
% of households that ate food not normally eaten		36	50	77	50	40	44

The pattern of consumption also changed in drought years in comparison with normal years. Rice was consumed by all farmers daily in normal years, but only 81% of the farmers consumed rice every day in drought years (Table 17). Similarly, the percentage of farmers consuming vegetables, pulses, fish, and milk on a daily basis declined in drought years. The increase in percentage of farmers consuming other crops such as wheat and millet indicates that these crops are being substituted for rice to a certain extent in drought years. In addition, farmers supplemented regular food with other items such as roots, weeds, banyan fruit, wild berries and nuts, snails, fermented rice, broken grains, and wasp eggs, which are not consumed normally (Table 16).

Table 17. Pattern of consumption of food in Orissa in normal and drought years.

Item	Consumed daily: Normal year (%)	Consumed daily: Drought year (%)	Consumed occasionally: Normal year (%)	Consumed occasionally: Drought year (%)
Rice	100	81	0	19
Wheat	6	20	36	31
Ragi	8	34	25	20
Other cereals	0	2	5	3
Pulses	22	6	48	23
Vegetables	77	28	23	56
Fruits	0	0	3	2
Fish	3	0	83	48
Meat	0	0	30	9
Milk	14	5	5	6
Oilseeds	95	52	5	42

Farmers undertook several adjustments to deal with the income shortfall caused by drought. Although income enhancement strategies such as additional employment in the nonfarm sector were sufficient in some cases, farmers had to take drastic steps in other cases, such as curtailing regular expenditures, reducing investments in assets, not maintaining assets, and selling assets (Table 18). Some of these strategies, while improving the chances of survival during drought years, could have long-lasting adverse effects on household welfare. Almost 80% of the households reduced expendi-

Table 18. Other household adjustments in response to the occurrence of drought.

Response	Balasore	Bolangir	Kalahandi	Khurda	Mayurbanj	Nawapara	All districts
	(% of households)						
Medical treatment postponed	40	100	40	77	50	90	67
Social obligation curtailed	40	100	50	77	70	90	72
Household expenditure curtailed	90	100	50	100	90	90	88
Animals sold	70	91	40	77	90	60	72
Land sold/leased out	80	36	10	23	30	20	33
Other assets sold (e.g., utensils)	50	55	20	85	60	40	53
Nonmaintenance of house	50			69	50		30
Children's education curtailed	20	9					5
Permanent migration		9					2
Migration for nonfarm activities	70	36	20	62	40	60	48
Mortgage/borrowing	80	91	30	100	50	70	72

tures on clothing, festivals, and social obligations. Some farmers had to postpone medical treatment of their ailments (67%). Some schoolchildren dropped out of school to engage in labor. In several cases, farmers reported an inability to thatch the roofs of their houses because of a lack of straw and were worried that the house could get damaged during the rainy season as a result. Some farmers were also concerned about the lack of seed for planting rice in the subsequent season.

The social consequences of drought and coping mechanisms relate mostly to dis-investment of farm capital. The sale of productive assets such as farm tools and bullocks can lead to a long-term decline in farm productivity. Heavy indebtedness, the potential threat of loss of land, the inability to continue children's education, and the social dislocation associated with permanent migration are some of the major social consequences of drought. While poor households are likely to be in this situation even under normal weather conditions, droughts severely stretch their capacity to cope. Most of the farmers interviewed reported suffering from stress and anxiety. In addition, poor mental and physical health due to postponement of medical expenditures, lower intake of food, and more laborious work are likely to compound the problem. The case of a family in Nawapara that was forced to sell a teenage child during the severe drought of the early 1980s is etched permanently in the history of Orissa (Sainath 1996).

Effectiveness of coping mechanisms

If farmers' coping strategies are ineffective and inefficient for stabilizing income and consumption, additional interventions through technology development and policy changes may be desirable. To judge the effectiveness of coping strategies, it is essential first to establish a norm against which the effectiveness can be assessed. One obvious indicator would be the extent to which farmers are able to smooth income and consumption. If long-term consumption is maintained at an acceptable level despite production shocks, one can conclude that farmers have been effective in coping with risk. Similarly, if income levels have been maintained despite a production shortfall, ex ante coping strategies can be considered to have been effective. However, if farmers have adopted conservative production practices that stabilize consumption but at a lower average level, the reduction in average consumption provides a measure of the cost of coping mechanisms. Thus, there are basically two measures of effectiveness. The first is the extent of the consumption shortfall during drought years. The lower the shortfall, the more effective the ex post risk-coping mechanisms will be. The second is the long-run consumption level. If the average level of consumption is lower than what could be expected for a given resource base and technological options available, the reduction in the average level of consumption is a measure of the cost of coping strategies. While the first measure is fairly easy to obtain through consumption surveys during drought and normal years, the estimation of the latter requires an in-depth analysis of the production system.

Estimating the magnitude of economic losses due to risk and risk aversion is complicated because ex ante and ex post mechanisms can substitute for and complement each other. Farmers' choices of ex ante mechanisms are conditional on what ex post mechanisms are available. For example, a relatively wealthy farmer who can draw upon savings to meet a production shortfall during years of low production is less likely to adopt conservative production practices. On the other hand, the effectiveness of ex post mechanisms may depend on the risk already averted by adopting conservative production practices (Morduch 1994). Thus, to measure the effectiveness of these strategies, both types of strategies need to be modeled simultaneously. Because of the complexity of such an exercise, a simple way is to obtain boundary estimates by assuming one of the mechanisms to be nonexistent. For example, upper-bound estimates of benefits from income-smoothing strategies can be obtained if consumption smoothing is assumed away by equating consumption with income. Similarly, upper-bound estimates of benefits from consumption smoothing can be obtained if income smoothing is assumed away.

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

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

The proportional risk premium is obtained as

$$P = 0.5\ R\ (CV_1^2 - CV_0^2)$$

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

Using the above formulation, variability in farm income could be used to judge the implicit cost of risk. A high CV of farm income is an indicator of the inability of ex ante mechanisms to stabilize income. For example, consider a situation where nonfarm income accounts for a negligible proportion of total income. If the CV of farm income is 0.6, the proportional risk premium for a moderately risk-averse farmer (i.e., a farmer with R = 2) will be 36% of the mean income. In other words, farmers would be willing to sacrifice up to 36% of their mean income to eliminate variability. Such a high proportional risk premium is an indicator of the ineffectiveness of ex ante risk management strategies. Of course, farmers may have considered the available ex ante options to be too costly in terms of the mean income forgone (i.e., income loss greater than 36%). Instead of sacrificing such a large proportion of mean income through ex ante strategies, farmers may have decided to live with such risk or use ex post strategies. The effectiveness of ex ante strategies can thus be considered to be greater when the CV of farm income is lower. Another somewhat imperfect indicator is the extent of an income shortfall in a drought year relative to income in a normal year. The larger the income gap, the less effective ex ante strategies are likely to be.

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

When risk management strategies for a specific crop such as rice are being considered, the cost of risk (or benefits from stabilization) depends on several parameters in addition to the CV of rice income (C_r). These additional parameters are the average share of rice income in total income (a), the CV of nonrice income (C_y), and the correlation coefficient between rice and nonrice income (g). In this case, the proportional risk premium is obtained as

$$P = 0.5\ R\ [a^2 C_r^2 + 2\ a\ (1 - a)\ g\ C_r C_y]$$

The first part of the equation captures the effect of stabilizing rice income. The lower the share of rice income, the smaller this benefit will be. The second part captures the effect resulting from the correlation of rice and nonrice incomes. The benefit from stabilization varies inversely with the correlation coefficient. The proportional risk premiums for the two villages in Faizabad, eastern India, were calculated on the assumption that g = 0.2. Other parameters were obtained from the panel data of farmers for four years. The estimated proportional risk premium was less than 1% of the mean income, indicating that full stabilization of rice income will generate only a small risk benefit in these villages (Table 19). A major reason for such a small benefit from the stabilization of rice income is a relatively low share of rice in the total farm income of the surveyed farmers. In Itgaon, the CV of rice income is high, but farmers seem to have managed the overall risk well by relying less on rice as a source of income. Even though the share of rice in the total income in Mungeshpur is higher, a relatively lower CV of rice income in this village resulted in a smaller benefit from stabilization. The share of rice in total income in Orissa is 23%. Under the parameterization used for Itgaon, the cost of risk is estimated to be around 6% of the mean income. Although this cost of risk does not seem as high as that suggested in the literature (Anderson 1995), for poor small farmers, this can be a very heavy burden to carry.

These rough orders of magnitude of the cost of risk are also supported by the size of the income shock during drought years. Farmers in Itgaon and Mungeshpur were able to maintain their income levels even during drought years. On the other hand, in Orissa, income during the drought of 1996 was only 67% of income during the previous normal year. These estimates indicate that, while ex ante risk management practices have been reasonably effective in Faizabad, these strategies were less effective in Orissa. In addition, the consumption-smoothing practices were unable to prevent a substantial drop in consumption of poor farmers in Orissa. The analysis of data from Orissa indicated that the consumption deficit of small farmers during the drought year 1996 was about 20% of the consumption during the previous nondrought year. This shortfall occurred in spite of a range

Table 19. Estimates of the proportional risk premium in selected villages in eastern India.

Location	Share of rice income	CV of rice income	CV of nonrice income	Proportional risk premium
		(%)		
Mungeshpur				
Small	12	39	24	0.61
Medium	17	10	25	0.17
Large	19	29	14	0.55
All	14	26	21	0.40
Itgaon				
Small	5	95	29	0.75
Medium	2	126	34	0.40
Large	6	94	17	0.68
All	5	90	24	0.61
Orissa				
All	23	90	24	6

of income- and consumption-smoothing strategies employed by farmers. The welfare consequences of such a shortfall could be substantial, especially for the poorer segments of the community. This magnitude of consumption shortfall indicates that farmers' risk-coping mechanisms were not very effective in dealing with drought risk. Obviously, if farmers had not used various strategies to deal with risk, the consumption shortfall could have been higher.

The differences in the effectiveness of adjustment mechanisms in Orissa and Uttar Pradesh are probably the result of differences in the structure of the rural economy. The level of infrastructure in Orissa is lower than in Uttar Pradesh (Bhatia 1999). Rural employment is more diversified in eastern Uttar Pradesh than in Orissa. As indicated by the data from Mungeshpur, farmers have diversified their income sources by engaging in nonfarm activities as well as through crop diversification. The expansion of tubewell irrigation in recent years must have induced crop diversification by facilitating cropping during the postrainy season. A better transportation infrastructure also would have encouraged diversification. In contrast, the rural economy of Orissa is less diversified, with rice production being the dominant economic activity. The proportion of area irrigated is less and the transportation infrastructure is less developed. As a result, farmers in Orissa seem not to be able to manage risk as well as their counterparts in eastern Uttar

Pradesh. This result indicates the potential role of investment in rural infrastructure and policies that encourage income diversification to improve the effectiveness of farmers' coping strategies.

The total economic cost of drought

We have attempted to extrapolate the production and employment losses to drought in eastern India based on the estimates derived from Orissa. While we recognize that the validity of such extrapolation over a wide geographical area and different production systems can be questionable, this approach has been taken to generate a ball-park figure. To the extent that the effect of drought is more severe in Orissa than in other states, production losses will be overestimated. A compensating factor, however, is that the probability of drought in Orissa is lower (0.25) than in other states of eastern India (0.34), except West Bengal. Using the estimated annual loss of 8% of the rice output in Orissa, the total annual loss for eastern India (total output of 21.5 million t, excluding West Bengal) is 1.7 million t. The economic value of this loss is $250 million. The value of the production loss of other crops in Orissa is 50% of the value of rice. Again using this figure to extrapolate, the total loss for eastern India is likely to be around $400 million per year. If we add to this the cost of relief operations and the costs absorbed by farmers internally through the use of various coping mechanisms, the total economic cost of drought for eastern India alone can rise to $500 million per year. Thus, the economic cost of drought in eastern India is certainly very high. Relative to this loss, the total current expenditure on agricultural research and education in eastern India is only about $40 million per year (Pal and Singh 1997). Investment in agricultural research and education certainly seems low relative to the size of the potential benefit that can arise from more effective drought mitigation.

Mitigating drought: opportunities for technological and policy interventions

The existence of a large potential benefit from drought mitigation in eastern India does not necessarily mean that additional resources should be allocated for this purpose. The resources that are needed to mitigate drought in eastern India may generate even more benefits if invested elsewhere. For research prioritization, it is essential to consider the additional benefits and additional costs, suitably adjusted by the probability of success, of alternative research projects and pick only those projects that generate the highest returns to society. Although the methodology for ex ante prioritization has been developed (Alston et al 1995), such an exercise is clearly beyond the scope of this project. Instead, we present some qualitative analyses to explore the potential value of drought mitigation vis-à-vis other types of research.

Long-term projections for rice demand and supply indicate that rice production needs to be increased by an additional 30–40% of the current value by 2020 to meet the extra demand from growing population (IRRI 1998). The failure to increase the supply to match the demand will raise the crop's price and make rice unaffordable to poor consumers. During the past two decades, the rapid growth in rice supply following the impressive success of the Green Revolution in Asian rice bowls has been the major factor in reducing the price of rice and keeping it low. The rates of returns to agricultural research that resulted in a massive increase in productivity in irrigated areas have been very high (Arndt et al 1977).

Will additional research investments in irrigated areas continue to generate such high economic returns or are marginal returns now higher in rainfed areas where drought is a serious constraint to rice production? Although this question has been of interest to the agricultural research community for some time, major efforts to address this question have not yet been made. However, some available evidence indicates that marginal returns to agricultural research in rainfed areas may now be higher than in irrigated areas. Based on an analysis of productivity data, Fan and Hazell (1999) have found that this is indeed the case for India. Similarly, the investment in infrastructure in rainfed areas was found to generate higher marginal returns than in irrigated areas.

The value of research investment in rainfed areas is often cast in terms of the debate on favorable versus marginal area (Byerlee and Morris 1994, Pinstrup-Anderson and Pandya-Lorch 1994, Heisey and Edmeades 1999). Those who advocate an increase in research resources in favorable environments argue that the efficiency gains are highest in favorable environments, whereas such gains are lower in fragile environments where the probability of research success is low. On the other hand, proponents of the increased emphasis on the fragile environments argue that marginal returns to research resources are now higher in such environments (Fan and Hazell 1999). The failure of the so-called "trickle-down" effect, the high incidence of poverty in fragile environments, and the high incidence of environmental degradation are additional factors proposed to justify increased research investment in fragile areas. While both camps have strong arguments, not enough analytical studies permit us to give a definite verdict on this debate. The outcome is probably context-specific, with one view or the other having a greater validity depending on the nature of the production system.

In the case of rice, the success of the Green Revolution in irrigated areas during the past three decades has made these areas the main rice bowl of the world. Irrigated ecosystems now generate more than 75% of the total rice supply although they account for only 55% of the total rice area. In spite of the overwhelming importance of irrigated ecosystems in generating the bulk of the rice supply, there are indications that this ecosystem alone will not be able to provide all the additional supply needed. Relatively higher costs associated with providing new irrigation facilities, the maintenance of the existing irrigation infrastructure, the trend toward diversification out of rice to maintain farm income, environmental concerns associated with further intensification of irrigated rice production, and the apparent lack of an economically exploitable "yield gap" are some of the major factors limiting the possibility of further increases in rice production from irrigated ecosystems (Rosegrant and Svendsen 1993, Pingali et al 1998).

The current yield of rainfed rice (milled) averages 1.2 t ha-I. Assuming that the area of irrigated and rainfed rice remains unchanged, the average yield of irrigated rice would have to increase to 5.4 t ha" by 2020 if the average yield in rainfed ecosystems remains constant at the current level of 1.2 t ha-I. Thus, the intensification pressure on irrigated environments will be very high if all of the additional demand for rice has to be met from this ecosystem. The level of inputs required for such high yields can also have adverse environmental effects. Improved technology for rainfed rice can help reduce intensification pressure in irrigated ecosystems. For example, if the yield of rainfed rice could be increased to 2 t ha-I, the average yield in irrigated environments would have to increase to 4.8 t ha" by 2020—still a high target, but a much more achievable one.

The above analysis indicates that additional research investments in rainfed rice areas are needed to enhance future food security, especially that of poor rural households. Rainfed rice area accounts for nearly 45% of the total rice area of the world and it is difficult to imagine how substantial progress in addressing the problems of food insecurity and poverty can be made without raising the productivity of rainfed environments. It is estimated that more than 500 million people depend directly on rainfed rice environments for their food security. These areas also have a very high incidence of poverty (Hossain 1995). The multiplier effect that will arise from a growth in rice productivity in these areas will certainly be critical to overall income growth and poverty reduction in rainfed environments.

Although drought has been recognized as a major constraint to rice production in rainfed areas, progress in developing appropriate interventions has been slow. In terms of developing rice varieties that are more tolerant of drought, the total amount of resources specifically devoted to addressing this issue has been very small relative to resources allocated to improving productivity in irrigated environments. Rainfed environments are highly heterogeneous, with moisture availability to rice varying even between fields. Rice plants may suffer from drought early in the growth season or during the late season, drought may be prolonged or intermittent, and it may vary in intensity throughout the growing season. As a result, a single ideotype will not be suitable for all drought-prone areas. In addition, drought tolerance is a complex trait that is most likely governed by several genes. The level of research investment needed to characterize the nature of drought adequately, develop a better understanding of genotype-environment interactions in drought-prone areas, and understand the physiological basis for drought tolerance will certainly be much higher than what has been allocated in the past.

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

Developing rice technologies to better manage drought, in addition to improving productivity in rainfed areas, is also likely to have spillover effects for irrigated areas. Available projections on global water availability indicate that the future supply to the agricultural sector is likely to diminish dramatically as the demand for water from industrial and urban sectors increases (IRRI 1995). Rice varieties that tolerate drought will be needed to maintain the productivity of irrigated rice in the face of the declining supply of irrigation. Given the critical importance of effective management of drought for enhancing food security and the availability of innovative tools, including molecular technology, it seems appropriate to reexamine the level of funding currently being allocated to drought research vis-à-vis other constraints such as pest management.

While technological interventions can be critical in some cases, they are not the only option for improving the management of drought. As discussed earlier, a whole gamut of policy interventions can improve farmers' capacity to manage drought through more effective income- and consumption-smoothing mechanisms. Improvements in rural infrastructure and marketing that allow farmers to diversify their income sources can play an important role in reducing overall income risk. Investments in rural education can similarly help diversify income. Such investments contribute directly to income growth that will further increase farmers' capacity to cope with various forms of agricultural risk. Widening and deepening of rural financial markets will also be a critical factor for reducing fluctuations in both income and consumption over time. Although the conventional forms of crop insurance are unlikely to be successful due to problems such as moral hazard and adverse selection (Hazell et al 1986), innovative approaches such as rainfall lotteries and international reinsurance of agricultural risk can provide promising opportunities (Walker and Ryan 1990, Gautam et al 1994). Improvements in drought forecasting and efficient provision of such information to farmers can improve their decisions regarding crop choice and input use (Abedullah and Pandey 1999). These institutional and policy interventions can be designed to complement technologies for maximum impact.

Concluding remarks

Although drought is an intrinsic feature of agriculture and human societies have over time learned to adapt in various ways to minimize its adverse consequences, the overall economic burden of drought is substantial. In addition, these adaptations have too often failed to prevent widespread famine, destitution, and death. There is no denying that human welfare is critically dependent upon our ability to manage drought better.

The estimated value of the average crop production loss caused by drought in eastern India is about $250 million per year. During drought years, the value of the production loss may be 2–3 times this value, especially when drought is severe and widespread. Drought reduces both the output of rice and that of post-rainy-season crops that grow on residual soil moisture. A drop in agricultural income caused by drought reduces income and employment in other rural sectors through its backward and forward linkages. Poor and disadvantaged groups suffer the most as they reduce consumption, sell assets, and, over time, become socially marginalized. Economic costs are also incurred when publicly sponsored relief operations are implemented during periods of severe drought. The overall economic cost of drought for eastern India alone could thus reach $500–600 million per year.

Because crop insurance programs are generally not economically viable due to the problems of adverse selection and moral hazard, farmers have developed several coping strategies. These strategies provide some degree of "self-insurance" to agricultural households by smoothing temporal fluctuations in income and consumption. While these strategies do protect households to a certain extent during mild droughts, they are ineffective when droughts are severe and widespread. In addition, the effectiveness of these strategies also depends on local environmental and economic conditions. Farm-level data from eastern Uttar Pradesh indicated that farmers who were unable to reduce variability in rice income by modifying production methods relied on nonfarm sources of income to reduce the impact of risk. Others attempted to reduce risk by investing in the development of irrigation. Yet, in parts of Orissa, economic and environmental conditions have constrained the use of these methods to reduce risk. As a result, farmers are bearing the cost of risk by adopting conservative production strategies that produce, on average, a lower level of income. The cost of risk bearing in Orissa was estimated to be 6–8% of mean income. This is a large burden, especially to poor farmers. Evidence from other countries and regions similarly shows that the effectiveness of coping mechanisms depends on environmental conditions. Obviously, technological and policy interventions that strengthen existing coping mechanisms are needed to generate the desired impact. Although the value of developing a deeper understanding of coping mechanisms for identifying promising intervention opportunities has been recognized in the risk literature, the research effort in this field has remained inadequate. One of the constraints has been the lack of a database of sufficient time length for a detailed study of farmers' responses to risk. Cross-sectional data are grossly inadequate for this purpose. Most of the empirical studies of coping mechanisms conducted during the last decade were based on the panel data developed by ICRISAT. Developing such data for representative locations in rice environments could similarly strengthen research on risk and its management.

In general, varieties that are drought-tolerant and crop management practices that increase water availability to plants improve farmers' risk-bearing ability by raising their mean incomes and simultaneously reducing income variability. The availability of credit and inputs, improved marketing infrastructure, irrigation, and rural education similarly help reduce and diffuse risk. In addition to improving risk management, these interventions are also critical to economic growth and poverty reduction.

Rice is the major staple of Asia. An adequate supply of rice to meet the increasing demand is of critical importance for food security in Asia. As rice production from rainfed areas is likely to be the major source of the additional supply in the future, it is imperative that more research be directed to tackling the various constraints to rice production in rainfed environments. Since drought is a major constraint in rainfed rice environments, investments for developing technical and policy interventions to reduce production losses to drought are bound to have high returns. Investments in developing rice technologies that can effectively alleviate drought in rainfed environments are also likely to have positive spillover effects in irrigated environments where the water supply is likely to be increasingly more limiting.

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About the authors

Sushil Pandey and Renato Villano are agricultural economist and assistant scientist, respectively, at the International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines; Dibakar Naik and Dev Dutt Behura are director and research assistant, respectively, Directorate of Planning, Monitoring and Evaluation, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, Orissa, India. The project was partially supported by a grant from The Rockefeller Foundation. The authors thank Shri Raj Kishore Bhujbal, vice chancellor, OUAT, for his support in this collaborative project between OUAT and IRRI. Assistance from Dr. John O'Toole, The Rockefeller Foundation, is gratefully acknowledged.

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