MINI REVIEW

Economic costs of drought and rice farmers' coping mechanisms

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Climate-related natural disasters (drought, flood, and typhoon) are principal sources of risk and uncertainties in agriculture. These are important constraints affecting the production of rice—the staple crop of Asia. Although the production of rice has increased over time in the wake of the green revolution, major shortfalls caused by climatic aberrations such as drought and flood are frequent. At least 23 million ha of rice area (20% of total rice area) in Asia is estimated to be drought-prone.

The economic costs of drought can be enormous. For example, drought has been historically associated with food shortages of varying intensities, including those that have resulted in major famines in different parts of Asia and Africa. In India, major droughts in 1918, 1957-58, and 1965 resulted in famines during the 20th century. The 1987 drought affected almost 60% of the total cropped area and 285 million people across India. Similarly, the average annual drought-affected area in China during 1978-2003 is estimated to have been 14 million ha and the direct economic cost of drought is estimated to have been 0.5-3.3% of the agricultural sector gross domestic product. In Thailand, the drought of 2004 is estimated to have affected 2 million ha of cropped area and over 8 million people.

The effect of drought on human societies can be multidimensional. The effect of drought in terms of production losses and consequent human misery is well-publicized during years of crop failure. However, losses to drought of milder intensity, although

not so visible, can also be substantial. Production loss, which is often used as a measure of the cost of drought, is only a part of the overall economic cost. Severe droughts can result in starvation and even death of the affected population. However, different types of economic costs arise before such severe consequences occur. Due to market failures, farmers attempt to 'self insure' by making costly adjustments in their production practices and adopting conservative practices to reduce the negative impact during drought years. Although these adjustments reduce the direct production losses, they themselves entail some economic costs in terms of opportunities for income gains lost during good years.

In rural areas where agricultural production is a major source of income and employment, a decrease in agricultural production will set off second-round effects through forward and backward linkages of agriculture with other sectors. A decrease in agricultural income will reduce the demand for products of the agro-processing industries that cater to the local markets. This will lead to a reduction in income and employment in this sector. Similarly, the income of rural households engaged in providing agricultural inputs will also decrease. This reduction in household incomes will set off further 'knock-on' effects. By the time these effects have been fully played out, the overall economic loss from drought may turn out to be several times more than what is indicated by the loss in production of agricultural output alone. The loss in household income can result in a loss in consumption of the poor whose consumption levels are already low. Farmers may attempt to cope with the loss by liquidating productive assets, pulling children out of school, migrating to distant places in search of employment, and going deeper into debt. The economic and social costs of all these consequences can indeed be enormous.

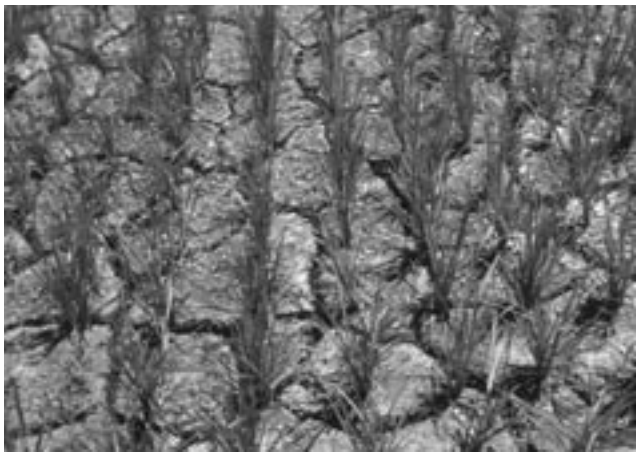
Much of the current knowledge on drought is based mainly on arid and semiarid regions. Despite reasonably high rainfall, drought occurs frequently in the subhumid regions of Asia. However, the nature and frequency of drought in subhumid regions, its impact on farmer livelihoods, farmers' drought-coping strategies, and welfare implications of drought have not been adequately studied. Analyses of drought characteristics, drought impacts, and household-coping mechanisms are important for understanding the nature of risk and vulnerability associated with drought and for formulating various interventions for effective drought mitigation.

This article provides a synthesis of findings and recommendations based on a recent cross-country comparative study of the impact of drought and farmers' coping mechanisms. The countries included in the study were China, India, and Thailand. These countries vary in climatic conditions, level of economic development, rice yields, and institutional and policy contexts of rice farming. The specific regions selected for the study were southern China, eastern India, and northeast Thailand. In southern China, the provinces included were Hubei, Guangxi, and Zhejiang. Eastern India was represented by the states of Chattisgarh, Jharkhand, and Orissa. All provinces of northeast Thailand were included.

Drought: definition, coping mechanisms, and consequences

Conceptually, drought is considered to describe a situation of limited rainfall that is substantially below what has been established to be a "normal" value for the area concerned, leading to adverse consequences on human welfare. Although drought is a climatically induced phenomenon, its impact depends on social and economic context as well. Hence, in addition to climate, economic and social parameters should be also taken into account in defining drought. This makes developing a universally applicable definition of drought impractical. Three generally used definitions of drought are based on meteorological, hydrological, and agricultural perspectives.

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



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

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

Ex-ante strategies can be grouped into two categories: those that reduce risk by diversification and those that do so by imparting greater flexibility in decisionmaking. 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. The examples include 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 decisionmaking permits farmers not only to reduce the chances of low incomes 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 the potential losses, such a strategy can also be costly in terms of income forgone if operations are delayed beyond the optimal biological window. Other ex-ante coping mechanisms include maintaining stocks of food, fodder, and cash.

Ex-post strategies are designed to prevent shortfall in consumption when the 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 the fluctuations in consumption. These include migration, consumption loans, asset liquidation, and charity. Consumption shortfall can occur despite these ex-post strategies if the drop in income is substantial.

Farmers who are exposed to risk use these strategies in different combinations. 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 deployed only under certain risky situations and are easier to identify as responses to risk.

Opportunity costs associated with the deployment of various coping mechanisms can, however, be large. The climatic uncertainties often compel farmers, particularly those who are more risk-averse, to employ conservative risk management strategies that reduce the negative impact in poor years, but often at the expense of reducing the average productivity and profitability. For example, by growing drought-hardy but low-yielding traditional rice varieties, farmers may be able to minimize the drought risk but may end up sacrificing a potentially higher income in normal years. Also, poor farmers in high drought-risk environments may be reluctant to invest on seed-fertilizer technologies that could increase profitability in normal years but lead to a loss of capital investment in poor years. In addition to these opportunity costs, poor households that are compelled to sell their productive assets such as bullocks and farm implements will suffer future productivity losses as it can take them several years to reacquire those assets. A cut in medical expenses and children's education will impact on future income-earning capacity of the household. Such an impact may linger on to the future generation also. The loss of income and assets can convert transient poverty into chronic poverty, making the possibility of escape from poverty more remote.

Analytical results

The analysis of monthly rainfall data for the period 1970-2003 indicated that drought is a regular phenomenon in the regions included in the study in all three countries. The probability of drought varied in the range 0.1–0.4, with the probability being higher in eastern India relative to southern China and northeast Thailand (Fig. 1). The probability of late-

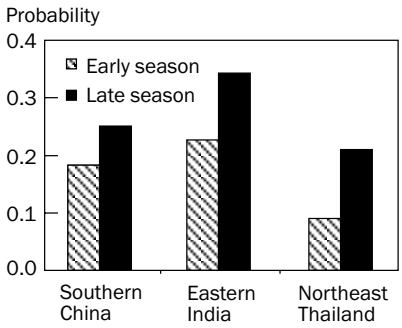


Fig. 1. Estimated probabilities of early- and late-season drought, in southern China (1982-2001), eastern India (1970-2000), and northeast Thailand (1970-2002).

season drought was found to be higher than that of the early-season drought generally. The late-season drought was also found to be spatially more covariate than the early-season drought. As rice yield is more sensitive to drought during flowering/grain-filling stages (i.e., during late season, according to the definition used here), the late-season drought is thus likely to have a larger aggregate production impact than the early-season drought.

The temporal instability in rice production as measured by the de-trended coefficient of variation of rice yield was found to be higher in eastern India relative to the other regions. The corresponding coefficients of variations for southern China and northeast Thailand were much lower, indicating that droughts in these regions are not as covariate spatially as in eastern India, with their effects being limited to some pockets. Given the nature of the temporal variability, the aggregate impact of drought on production is also likely to be higher in eastern India relative to the other two regions.

The estimated average loss in rice production during drought years for the three states of eastern India is 5.4 million tons. This is much higher than for northeast Thailand (less than 1 million tons) and southern China (around 1 million tons but not statistically significant). The loss (including any nonrice crops included) during drought years is thus 36% of the average value of production in eastern India. This represents indeed a massive loss during drought years (estimated at $856 million).

As droughts do not occur every year, the above estimate of production loss needs to be averaged over a run of drought and nondrought years to get an annual average loss estimate. Again for eastern India, this represents an annual average loss of $162 million (or 6.8% of the average value of output). For northeast Thailand and southern China, the losses were found to be much smaller and averaged at less than $20 million per year (or less than 1.5% of the value of output).

The estimates thus indicate that, at the aggregate level, production losses are much higher for eastern India than for the other two regions. Lower probability of drought, smaller magnitude of loss during drought years, and less covariate nature of drought together resulted in a lower production loss at the aggregate level in the other two regions relative to eastern India.

The overall economic cost of drought includes the value of production loss, the costs farmers incur in making adjustments in production systems during drought years, opportunities for gains forgone during good years by adopting ex-ante coping strategies that reduce losses during drought years, the generally lower productivity of drought-prone areas due to moisture deficiency, and the costs of government programs aimed at long-term drought mitigation. The public-sector provision of relief also involves large financial costs, but these are mainly transfer payments, and hence, do not involve an economic cost. The average annual cost for the three states of eastern India included in this study is in the neighborhood of $400 million. Overall, the cost of drought is a substantial proportion of the agricultural value added in eastern India.

The household-level impact of drought presented here is based mainly on the study in eastern India. Relative to eastern India, impact in northeast Thailand and southern China was found to be quite small and hence, is not discussed here.

Drought resulted in an overall income loss in the range of 24-58%. The drop in rice income was the main factor contributing to the total income loss. Earnings from farm labor also dropped substantially due to a reduced labor demand. Farmers attempted to reduce the loss in agricultural income during drought years by seeking additional employment in the nonfarm sector. This mainly included employment as wage labor in the construction sector for which farmers often migrated to distant places. The additional earning from nonfarm employment was, however, clearly inadequate to compensate for the loss in agricultural income.

Farmers relied on three main mechanisms to recoup this loss in total income. These were the sale of livestock, sale of other assets, and borrowing. These adjustment mechanisms helped recover only 6-13% of the loss in total income. Compared with the normal years, households still ended up with a substantially lower level of income despite all these adjustments. Thus, all the different coping

mechanisms farmers deployed were found to be inadequate to prevent a shortfall in income during the drought years.

The incidence of poverty increased substantially during drought years. Almost 13 million additional people "fell back" into poverty as a result of drought (Fig. 2). This is a substantial increase in the incidence of poverty and translates into the increase in rural poverty at the national level by 1.8 percentage points. Some of the increase in poverty may be transitory, with households being able to climb out of poverty on their own. However, other households whose income and assets fall below certain threshold levels may end up joining the ranks of the chronically poor. The data collected, however, did not permit the estimation of the proportion of these two categories of households.

Overall, farmers do not seem to have much flexibility in making management adjustments in rice cropping in relation to drought. Other than delaying the crop establishment if the rains are late, replanting and resowing when suitable opportunities arise, and some reduction in fertilizer use, farmers mostly follow a standard set of practices irrespective of the occurrence of drought. This could partly be due to the fact that drought mostly occurs during the late season, by which time the opportunities for crop management adjustments to reduce losses are no longer available. The timing of drought (mostly late rather than early) and the lack of suitable technological options probably limited the flexibility in making tactical adjustments in crop management practices to reduce the losses.

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

Farmers made all these types of adjustments to a varying degree. Despite these various adjustments, most farmers were unable to maintain consumption at the pre-drought level. They reduced both the number of meals taken per day as well as the quantity consumed per meal. As a result, the average number of meals taken per day dropped from close to three to close to two, with 10-30% of the households reducing their frequency of food intake to one meal per day. A large proportion (60-70%) of the households also reduced the quantity of food consumed per meal. In addition, households consumed other "inferior" food items that were not normally consumed.

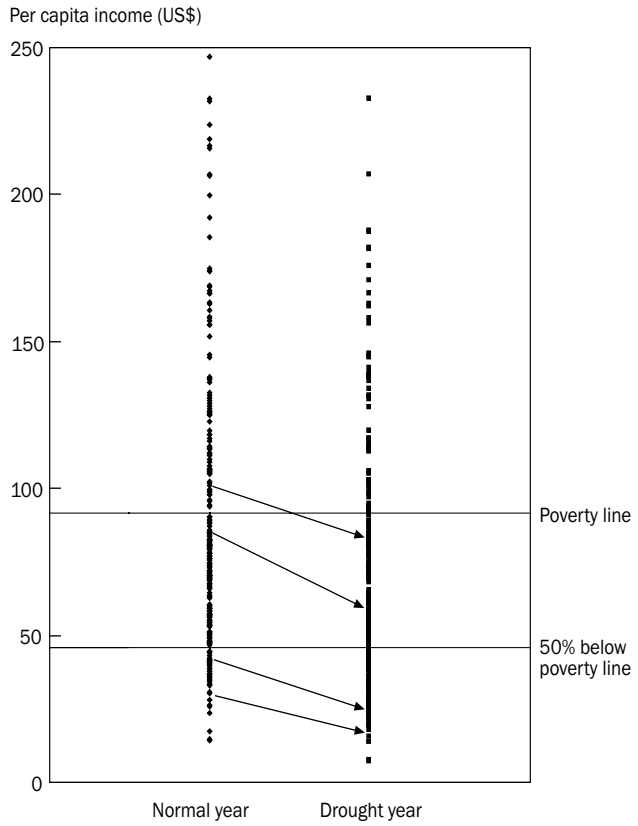


Fig. 2. Effect of drought on incidence and severity of poverty phenomenon, Jharkhand (each dot refers to a household).

The interruption and/or discontinuation of children's education is a disinvestment in human capital, which will most definitely reduce their future earning potentials in most cases. An important pathway for escape from poverty may be foreclosed as a result of drought. More than 50% of the farmers reported curtailing children's education.

Relative to eastern India, the economic costs in southern China and northeast Thailand were found to be small, both in absolute and relative terms. The production losses at the aggregate level in these two regions were relatively small due to a lower frequency and less covariate nature of drought. In addition, rice accounted for a smaller proportion of the household income due to a more diversified income structure. The differences in the rice production systems, the level of income diversification, and the nature of drought in these two latter regions are hence, the major factors determining the relative magnitudes of economic losses.

In the case of eastern India, rice accounts for around 40% of the total household income. The share of rice in the total household income in south-

ern China and northeast Thailand is about half that in eastern India. Eastern Indian farmers thus lose proportionately more income during drought years. Due to limited diversification of farm income, which is generated mainly from rice, the household-level consequences of drought in eastern India are thus more severe relative to the other two regions. In both northeast Thailand and southern China, agricultural income is more diversified. In addition, the share of nonfarm income in the total income is much higher. Thus, a more commercialized agriculture and a greater diversification of farm incomes seem to have contributed to a smaller consumption consequence of drought in southern China and northeast Thailand relative to eastern India by weakening income correlations and improving the effectiveness of coping mechanisms. The effect of these factors on household-level impact is stylized in a summary form in Figure 3.

Drought mitigation options

Improved rice technologies that help reduce the losses to drought can play an important role in long-term drought mitigation. Important scientific progress is being made in understanding the physiological mechanisms that impart tolerance for drought. Similarly, progress is being made in developing drought-tolerant rice germplasm through conventional breeding and the use of molecular tools. The probability of success in developing rice germplasm that is tolerant of drought is likely to be substantially higher now than what it was 10 years ago. Complementary crop management research to manipulate crop establishment, fertilization, and general crop care for avoiding drought stress, better utilization of available soil moisture, and enhancing the plant's ability to recover rapidly from drought can similarly help reduce the losses.

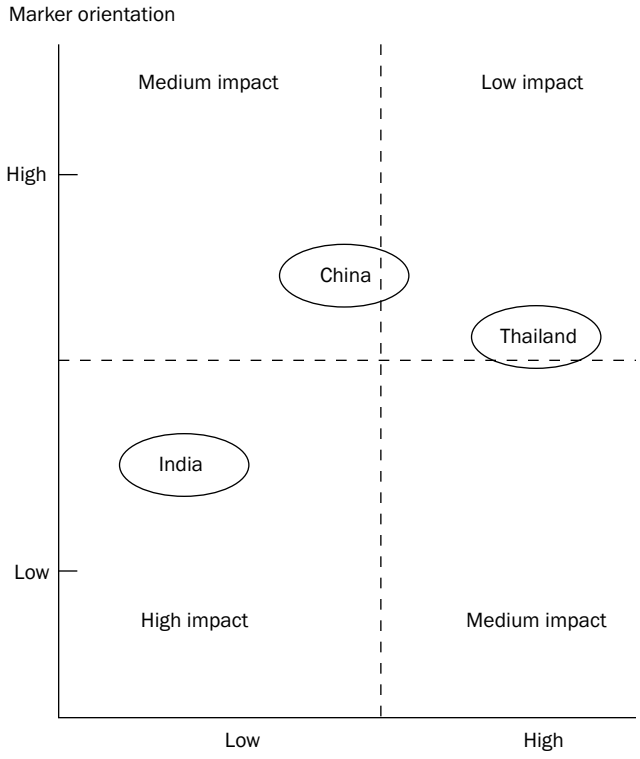


Fig. 3. Household-level impact of drought.

The late-season drought is more frequent and tends to have more serious economic consequences for poor farmers than the early-season drought. In addition to having to deal with consequences of low or no harvest, farmers also lose their investments in seeds, fertilizers, and labor if the crop is lost due to late-season drought. Although early-season drought may prevent planting completely, farmers can switch early to other coping strategies such as wage labor and migration to reduce income losses in such years. Thus, the poverty impact of technology is likely to be higher if research is focused on developing technologies that help plants better tolerate the late-season drought.

Crop diversification is an important drought -coping mechanism of farmers. Rice technologies that promote, not constrain, such diversification are, hence, needed. In rainfed areas, shorter duration rice varieties can facilitate planting of a second crop using the residual moisture. Similarly, rice technologies that increase not just the yield but also the labor productivity will facilitate crop and income diversification. Higher labor productivity in rice production will help relax any labor constraint to diversification that may exist. Examples of such technologies are selective mechanization, direct seeding, and chemical weed control.

Development of water resources is an important area that is emphasized in all three countries for providing protection against drought. Opportunities of large-scale development of irrigation schemes that were the hallmark of green revolution are limited now due to high costs and increasing environmental concerns. However, there are still substantial opportunities to provide some protection from drought through small and minor irrigation schemes and through land use approaches that generally enhance soil moisture and water retention. Similarly, watershed-based approaches that are implemented in drought-prone areas of India provide opportunities for achieving long-term drought proofing by improving the overall moisture retention within the watersheds.

In all three countries studied, a major response to drought has been to provide relief to the affected population. India has the most elaborate institutional setup for providing drought relief, which mainly takes the form of employment generation through public works. Affected people are also provided with some inputs and credit. While the provision of relief is essential to reduce the incidence of hunger and starvation, the major problems with the relief programs are slow response, poor targeting of beneficiaries, and limited coverage due to budgetary constraints. A 'fire-fighting' approach that underlies the provision of drought relief cannot provide a long-term drought proofing despite the large amount spent during the drought years. It is important that the provision of relief during drought years is complemented by a long-term strategy of investing in soil and water conservation and utilization, policy support, and infrastructure development to promote crop and income diversification in drought-prone areas.

The scientific advances in meteorology and informatics have made it possible now to forecast drought with reasonable degrees of accuracy and reliability. Various indicators such as the Southern Oscillation Index are now routinely used in several countries to make drought forecasts. Suitable refinements and adaptations of these forecasting systems are needed to enhance drought preparedness at the national level as well as to assist farmers in making more efficient decisions regarding the choice of crops and cropping practices.

While technological interventions can be critical in some cases, this is not the only option for improving the management of drought. There is a whole gamut of policy interventions that can improve farmers' capacity to manage drought through more effective income- and consumption-smoothing mechanisms. Improvements in rural infrastructures and marketing that allow farmers to diversify their income sources can play an important role in reducing the overall income risk. Investment in rural education can similarly help diversify income. In addition, such investments contribute directly to income growth that will further increase farmers' capacity to cope with various forms of agricultural risks. Widening and deepening of the rural financial markets will also be a critical factor for reducing fluctuations in both income and consumption over time. Although the conventional forms of crop insurance are unlikely to be successful due to problems such as moral hazard and adverse selection, innovative approaches such as rainfall derivatives and international re-insurance of agricultural risks can provide promising opportunities. However, these alternative schemes have not yet been adequately evaluated. There are important challenges in employing weather-risk markets in developing countries. More work is needed for developing and pilot testing new types of insurance products and schemes suited to hundreds of millions of small farmers of Asia who grow rice primarily for subsistence.

Concluding remarks

Even in subhumid rice-growing areas of Asia, drought is clearly an important climatic factor that has large economic costs, both in terms of the actual economic losses during drought years and the losses arising from the opportunities for economic gains forgone. The provision of relief has been the main form of public response to drought. Although important in reducing the hunger and hardship of the affected people, the provision of relief alone is clearly inadequate and may even be an inefficient response for achieving longer term drought mitigation. Given the clear linkage between drought and poverty as demonstrated in this study, it is critically important to include drought mitigation as an integral part of the rural development strategy. Policies that in general increase income growth and encourage income diversification also serve to protect farmers from the adverse consequences of risk, including that of drought.

The scientific progress made in understanding the physiology of drought and in the development of biotechnology tools have opened up promising opportunities for making a significant impact on drought mitigation through improved technology. However, agricultural research in general remains grossly underinvested in developing countries of Asia. This is a cause for concern, not only for drought mitigation, but for promoting an overall agricultural development.

This is an overview of the book ***Economic costs of drought and rice farmers' coping mechanisms*** edited by S. Pandey, H. Bhandari, and B. Hardy. See back cover for details.