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Coping with drought in rice farming in Asia: insights from a cross-country comparative study

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Abstract

Drought is a major constraint affecting rice production especially in rainfed areas of Asia. Despite its importance in rice growing areas, the magnitude of economic losses arising from drought, its impact on farm households and farmers' drought coping mechanisms are poorly understood. This paper provides insights into these aspects of drought based on a cross-country comparative analysis of rainfed rice growing areas in China, India and Thailand.

The economic cost of drought is found to be substantially higher in eastern India than in the other two countries. Higher probability and greater spatial covariance of drought and less diversified farming systems with rice accounting for a larger share of household income are likely to be the main reasons for this higher cost of drought in eastern India. Farmers deploy various coping mechanisms but such mechanisms are largely unable to prevent a reduction in income and consumption, especially in eastern India. As a result, welfare consequences on poor farmers are substantial with a large number of people falling back into poverty during drought years. The overall implications for technology design and for policy improvements for drought mitigation and drought relief are discussed in the light of the empirical findings of the study.

JEL classification: D1; I3; Q1

Keywords: Drought; Economic cost; Coping mechanisms; Poverty

Introduction

Climate related natural disasters (drought, flood, and typhoon) are the principal sources of risk and uncertainties in agriculture. Wide fluctuations in agricultural output that have occurred throughout the human history attest to the fact that agriculture is an economic activity dependent on the vagaries of weather. While attempts have been made to reduce the adverse effects of weather on agriculture through scientific research and technology development, the performance of agriculture, especially in developing countries, still depends largely on the weather.

Rice is a staple crop of Asia. Although the production of rice has increased over time in the wake of 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 (Pandey et al., 2006).

The economic costs of drought can be enormous. For example, drought has been historically associated with food shortages of varying intensities, including those that have resulted in major famines in different parts of Asia and Africa. In India, major droughts in 1918, 1957-58, and 1965 resulted in famines during the 20th century (FAO, 2001). The 1987 drought affected almost 60% of the total cropped area and 285 million people across India (Sinha, 1999). Similarly, the average annual drought-affected area in China during 1978-2003 is estimated to be 14 million ha and the direct economic cost of drought is estimated to be 0.5-3.3% of the agricultural sector GDP. In Thailand, drought of 2004 is estimated to have affected 2 million ha of cropped area and over 8 million people (Bank of Thailand, 2005; BBC News, 2005; Asia Times, 2005).

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 (often a small 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 distance 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 semi-arid regions (Jodha, 1978; Campbell, 1999; Hazell et al., 2001; Shivakumar and Kerbart, 2004; Rathore, 2004). Despite reasonably high rainfall, drought occurs frequently in the sub-humid regions of Asia (Steyaert et al., 1981). However, the nature and frequency of drought in sub-humid regions, its impact on farmer livelihoods, farmers' drought coping strategies and welfare implication 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 research report provides a synthesis of findings and recommendations based on a recent study which involves a cross-country comparative study of the impact of drought and farmers' coping mechanisms². The countries included in the study were China, Thailand and India. These countries vary in climatic conditions, the level of economic development, rice yields, and institutional and policy contexts of rice farming. The specific regions selected for the study were eastern India, northeast Thailand, and southern China. Eastern India was represented by the states of Chattisgarh, Jharkhand and Orissa. In southern China, the provinces included were Hubei, Guangxi and Zhejiang. All provinces of northeast Thailand were included. Some of the basic characteristics of rice production systems and economic indicators of the countries/regions in the study are summarized in Table 1.

² Pandey, S., and Bhandari, H., editors. 2006. Economic costs of drought and rice farmers' coping mechanisms: a cross-country comparative analysis from Asia. International Rice Research Institute (IRRI), Los Banos, Philippines. (Forthcoming).

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 while 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 (Wilhite and Glantz, 1985).

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 sub-surface 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, definition of agricultural drought requires consideration of actual and potential evapotranspiration, soil water deficit, and production losses simultaneously.

Risk-coping³ 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 decision making. Diversification is simply captured in the principle of not putting “all eggs in one basket”. The risk of income shortfall is reduced by growing several crops that have negatively or weakly correlated returns. This principle is used in different types of diversification common in rural societies. The examples include spatial diversification of farms, diversification of agricultural enterprises and diversification from farm to non-farm activities.

Maintaining flexibility is an adaptive strategy that allows farmers to switch between activities as the situation demands. Flexibility in decision-making permits farmers not only to reduce the chances of low incomes but also to capture income-increasing opportunities when they do arise. The 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.

³ In the risk management literature, a distinction is often made between adaptive strategies that reduce risk and others that are utilized to deal with the losses that do occur (Davies, 1996). The term ‘coping’ is used in this conceptualization to refer to the latter set of strategies only. As argued by Dercon (2002), these two sets of strategies are related, not independent.

While postponing agricultural decisions until uncertainties are reduced can help lower the potential losses, such a strategy can also be costly in terms of income forgone if operations are delayed beyond the optimal biological window.

Ex-post strategies are designed to prevent shortfall in consumption when 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 the 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 (Anderson, 2001; Hansen, 2002). For example, by growing drought-hardy but low-yielding traditional rice varieties, farmers may be able to minimize the drought risk but will end up sacrificing a potentially higher income in normal years. 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. Anderson (1995) estimated the economic cost of risk aversion in rice production in developing countries to be around 10%

of the average income. Likewise, Antle (1987) showed a 14% reduction in expected net profit due to inefficiency in labor allocation. Although the inefficiency cost may appear to be small in percentage terms, this involves a substantial reduction in the average income of poor farmers who are on or barely above the poverty line.

In addition to these opportunity costs, poor households who 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 impact may linger on to the future generation also. The loss of income and asset can convert transient poverty into chronic poverty, making the possibility of escape from poverty more remote (Morduch, 1994; Barrett, 2005).

Analytical approach

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

The estimation of aggregate production loss involved the analysis of published temporal data on rainfall and crop production. Province (or state) and county (or district) level data were utilized for this (Table 2). These data were also used to estimate the aggregate economic losses from drought by correlating drought events with crop production. Actual crop production over a run of years covering both drought and non-drought years were utilized in this study as opposed to the usual practice of subjectively estimating the production loss using either farmers' or

researchers' subjective estimate of yield losses and probability of drought (Widawsky and O'Toole, 1990; Hossain, 1996; Gypmantasiri et al., 2003).

Drought was defined in terms of deficiency of actual rainfall compared to the long-term average (LTA) rainfall. Following the similar approach used by Indian Meteorological Department (IMD) and other literatures (Pandey et al., 2000; DAC, 2003), drought was considered to occur in a particular year if the annual rainfall is less than 80% of the LTA. The main focus of this study is on rice which is grown mainly during the monsoon season. Hence, in the context of this study, drought was considered to have occurred if rainfall during the monsoon season is less than 80% of the LTA. The frequency of drought was estimated as the ratio of the number of drought years to the total number of years considered. Characterization of the timing, intensity, frequency, and spatial pattern of drought was conducted using the long-term monthly rainfall data. Province (or state) and county (or district) level data were utilized for this.

The rice-growing period was divided into three growing seasons for assessing the incidence of drought during different periods and its impact on production. These were early, medium and the late seasons. Frequency of drought during each season was estimated as the number of years in which rainfall was below 80% of the LTA for that particular season.

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

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

$$Q = a + b T + c D + u \quad (1)$$

Where, T refers to the time trend which captures the effect of technological change and D is the drought dummy. The drought dummy variable takes the value of '1' in drought years and '0' otherwise. The coefficient 'c' measures the average effect of drought on production when all drought years are considered.

The analysis of the household-level impact of drought and farmers' coping mechanisms was conducted using cross-sectional data from a survey of farm households. For this, households were selected from study areas using a stratified random sampling approach (Table 3). Detailed information of cropping patterns, rice production, household income, employment, and drought coping mechanisms were elicited during the survey using pre-tested survey questionnaires. Farmers were asked to provide information on production practices and farm productivity for "normal" and "drought" years. Information on the overall impact of drought on income and how households attempted to cope with drought was also collected during the survey. The collected information was compared between "normal" and "drought" years to analyze the impact of drought.

The meteorological definition of drought used for the aggregate analysis is inappropriate for estimating the household-level impact. A village may suffer from drought in a particular year even though the meteorological data do not indicate drought at the aggregate (province/state/zone) level. Thus a village-based identification of a "normal" and a "drought" year experienced in the recent past was utilized.

Results and discussions

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 (Figure 1). The probability of late 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 fill 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 high in eastern India relative to the other regions. The nature of instability is typically illustrated by the yield trend in Orissa (Figure 2). Such a high-level of instability over the whole of the state (with the average rice area of 4.5 million ha) is indicative of a high frequency and covariate nature of drought. The corresponding coefficients of variations for southern China and northeast Thailand were much lower (Table 4) indicating that droughts in these regions are not covariate spatially, with their effects being limited to some pockets. Given the nature of the temporal variability, the aggregate impact of drought on production 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 using the dummy variable model described earlier for the three states of eastern India is 5.4 million tons (Table 5). 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 non-rice 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 non-drought years to get the annual average loss estimate. Again for eastern India, this represents the annual average of loss of \$162 million (or 6.8% of the average value of outputs). 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, the 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 have reduced the production loss at the aggregate level in the other two regions relative to eastern India.

The overall economic cost of drought include 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 risk-averse strategies that reduce losses during drought years, the generally lower productivity of drought-prone areas due to moisture deficiency, and costs of government programs for drought alleviation and provision of relief. The average annual cost for the three states of eastern India included in this study is in the neighborhood of \$400 million (Pandey and Bhandari, 2006). The share of the value of production loss in this total is around 40%. The ex-ante economic cost associated with the opportunity loss resulting from a lower average productivity and the use of conservative

practices accounts for over 50% of this total⁴. 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 were found to be quite small and hence, are not discussed here.

Drought resulted in an overall income loss of about 24% and 26% in Jharkhand and Orissa, respectively (Table 6). The magnitude of loss was much higher at 58% in Chattisgarh where the impact of drought was much more severe. Almost complete failure of the rice crop in Chattisgarh led to a much larger proportionate income loss in that state. 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 non-farm sector. This mainly included employment as wage labor in the construction sector for which farmers often migrated to distant places. The additional earning from non-farm employment was, however, clearly inadequate to compensate for the loss in agricultural income, thus resulting in a drop in total income of 24-58%.

Farmers relied on three main mechanisms to re-coup 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 to the normal years, households still ended up with substantially lower level of income despite all these adjustments. Thus, all different coping mechanisms farmers deployed were found to be inadequate to prevent a shortfall in income during the drought years.

⁴ Estimates of these two components could not be obtained separately due to data limitations.

The above analysis provides a general picture of the overall impact of drought on the farm income. This impact is likely to differ across the farm size groups given the differences in their income strategies. Crop production loss is expected to have a smaller proportionate effect in the income of smaller farm size categories as they derive relatively less income from crop production. This was indeed the case with the sample data. The proportionate loss in the total income of small and marginal farmers was indeed less than that of the medium and large farmers. For example, the total loss in income of small and marginal farmers was 17-42% while that of the medium and large farmers was 25-67%.

Despite this lower proportionate loss, the welfare effect of income loss is likely to be more severe for small and marginal farmers who earn a much lower level of income even during the normal years. For example, marginal farmers earned only 16-25% of the income of larger farm size categories. The marginal and small farm size groups are thus more likely to “fall back” into poverty drought years than the other two farm size groups.

The incidence of poverty increased substantially during drought years (Table 7). Almost 13 million additional people “fell back” into poverty as a result of drought. 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 household being able to climb out of poverty on their own. However, other households whose income and asset fall below certain threshold levels may end up joining the ranks of the chronically poor (Barrett, 2005). The data collected, however, did not permit the estimation of the proportion of these two categories of households.

The effect of drought on the incidence and severity of poverty is illustrated graphically through an example from Jharkhand (Figure 3). Each dot in the diagram represents the income

level of a person in relation to the overall poverty line and the arrows indicate the transition to another income level during the drought years. As indicated, the overall incidence of poverty increased during the drought years as some people who were above the poverty line fell back to poverty. Others who were already below the poverty line got pushed further deeper into poverty.

Overall, farmers do not seem to have much flexibility in making management adjustments in rice crop 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 for reducing losses are no longer available. The timing of drought (mostly late rather than early) and the lack of suitable technological options probably has 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 amount of purchase, substitution of other crops for rice, supplementation of food deficit by other types of food not normally consumed, and in the worst-case scenario, a reduction in consumption.

Farmers made all these types of adjustments to a varying degree. One of the major effects of production loss is severe reduction in sale, the quantity of seeds kept for the subsequent year, and the quantity stored for future use. The quantity of rice sold during drought years decreased by 82-98% as compared to the normal year. This reduction in the marketed quantity would obviously have a price effect in the local market, which if not counteracted by inflow of grains

from other areas, will result in an overall reduction in consumption per capita. This price effect may help stabilize income of those who are rice sellers. However, such price increases will have a regressive impact on the welfare of poor laborer and marginal farmers who spend a larger share of their income on rice purchase.

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

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 consumed⁵.

Forced adjustment in expenditure is a logical consequence of income loss. Reduced expenditure on some non-essential items such as clothing and social functions may not have much welfare implications. However, farmers often reduce expenditure even on essential items like food and medical treatments. Such expenditure cuts are most likely to result in adverse short and long-term consequences. More than 50% of the farmers also reported curtailing children’s education. This occurs for three reasons. First, parents may be unable to meet the recurring cost

⁵ Such consumption items include wild flowers and fruits, wild roots and tuber crops (*konda*), wild leaves and vegetables, Kendu fruits, boiled Mahua flower, minor millets, broken rice, and boiled maize.

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

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 southern China and northeast Thailand is about half that in eastern India. Eastern Indian farmers thus lose proportionately more income during drought years. Due to limited diversification of farm income, the household level consequences of drought in eastern India are thus more severe relative to the other two regions. In both northeast Thailand and southern China, agricultural income has become more diversified away from rice towards commercial field crops. In addition, the share of non-farm 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 4.

Drought mitigation options

Despite the critically important role of research in raising agricultural productivity and reducing poverty, the level of agricultural research in developing countries is generally low. While industrialized countries invest about 2.6% of their agricultural GDP in research, the research intensity (or the ratio of research expenditure to agricultural GDP) for developing countries has been estimated to be around 0.62% (Pal and Byerlee, 2003). In the case of China and India, the research intensities are only 0.43% and 0.29%, respectively. Clearly, agricultural research in developing countries of Asia remains underinvested. The total agricultural research investment in India in 1998/99 was about US\$430 million (Pal and Byerlee, 2003). The economic losses from drought alone as estimated in this study by considering just the rainfed rice growing areas is close to this figure.

The allocation of research resources to rainfed areas and specifically to address abiotic constraints such as drought and submergence are even lower relative to the size the economic costs arising from these constraints. A recent study from India illustrates the case in point. It has been found that the allocation of rice research resources to rainfed areas in India is disproportionately small relative to the potential contribution of these areas in making efficiency

and equity impacts (Pandey and Pal, 2005). The share of even this limited amount of resources targeted to address abiotic constraints such as drought and submergence is less than 10%.

Thus there is a clear justification for increasing the research intensity in agriculture and allocating a larger proportionate share to rainfed areas to address drought and submergence which are the dominant constraints to productivity growth. It has been established that the marginal productivity of research resources may now be higher in rainfed environments than in irrigated environments and that agricultural research in unfavorable (rainfed) environments can generate a substantial poverty impact (Fan et al., 2003). Important progress has been made in understanding the physiological mechanisms that impart tolerance to drought (Blum, 2005; Boyer, 2005; Lafitte, 2005). Similarly, important progress is being made in developing drought-tolerant rice germplasm through conventional breeding and the use of molecular tools (Bennett, 1995; Atlin et al., 2005; Serraj, 2005). The probability of success in developing rice germplasm that is tolerant to 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 plant's ability to recover rapidly from drought can similarly yield high returns. For effective drought mitigation, an important design criterion for technology development is to improve farmers' flexibilities in their decisions regarding the crop choices, the timing and methods of crop establishment, and the timing and quantity of various inputs to be used. Flexibility in agricultural technologies permits farmers not only to reduce the chances of low incomes but also to adaptively capture income-increasing opportunities when they do arise. Technologies that lock farmers into a fixed set of practices and timetable do not permit effective

management of risk in agriculture. In fact, the empirical analyses presented in this report indicate that the current rice production practices, especially in drought prone areas of India, are somewhat inflexible and routine. Rice varieties and general crop management practices used are almost the same in normal years and in years with early season drought. Examples of technologies that provide greater flexibilities are varieties that are not adversely-affected by delayed transplanting caused by early season drought, varieties that perform equally well under both direct seeding and transplanting, and crop management practices that can be implemented over a wider time window.

The late-season drought is more frequent and tends to have more serious economic consequences to 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 damaged by late season drought. Although early season drought may prevent planting completely, farmers can switch early to other coping strategies such 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 which 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 much limited now due to high costs and increasing environmental concerns (FAO, 1997; Rosegrant et al., 2002; Gulati et al., 2005). However, there are substantial opportunities still to provide some protection from drought through small and minor irrigation schemes and through land use approaches that generally enhance soil moisture and water retention. In the Indo-gangetic plains, supplemental irrigation from tubewells, minor lift irrigation schemes, dugwells and community ponds is widely practiced (Shah, 1993; Shah, 2001a; Moench, 2002). In China and in Thailand, the use of farm and community ponds is also common. These small private or community-owned schemes tend to be low cost and sufficiently responsive to the local needs. Similarly, watershed-based approaches that are implemented in drought-prone areas of India provide opportunities for achieving long-term drought proofing by improving the overall moisture retention within the watersheds (Rao, 2000). Public sector support for further development, maintenance and rehabilitation of these schemes could make them more effective in mitigating drought. The public sector involvement, however, should be limited to the provision of technical assistance while the actual management of these small scale-schemes is better left to the local communities (Turton, 2000; Shah, 2001b; Kerr et al., 2002).

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 set-up 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 can not provide a long-term drought proofing despite the large amount spent during the drought years (Rao, 2000; Hirway, 2001). It is important that this ‘fire-fighting’ approach is replaced 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, and encouraging community participation in managing and augmenting local water resources. Important progress is being made through watershed development programs in various parts of India but these programs are not sufficiently integrated with the overall agricultural development activities thus diluting their potential impact. In addition, decentralized institutional set-up that promotes greater participation and decision making by local-level agencies is needed to improve the overall effectiveness of relief programs which mostly tend to be top-down in design.

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 (SOI) are now routinely used in several countries to make drought forecasts (Wilhite et al., 2000; Hansen, 2002; Zschau and Kueppers, 2003; Meinke and Stone, 2005). Suitable refinements and adaptations of these forecasting systems are needed for enhancing 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 (Abedullah and Pandey, 1999). Currently, rice farmers in Asia do not generally receive much advance warning of impending drought. Even when general forecasts regarding the likelihood of drought are made, these are seldom translated adequately into the form that is useful for agricultural decision-making. Improvements in drought forecasting systems, identification of efficient agricultural

management practices to reduce the impact of drought, and provision of timely advice to farmers are activities that can help reduce the overall economic cost of drought and improve preparedness to deal with the inevitable consequences of drought.

Although drought occurs regularly and the governments respond with the provision of relief and other forms of assistance to the affected communities, detailed scientific characterization of drought, analysis of its impact, and mapping are not being adequately conducted both at the local (province, district, state) and the national levels. Such analyses and mapping are critically important for developing and implementing suitable short and long-term strategies for drought mitigation. For example, in the study areas in China and Thailand, local authorities were not able to provide much information regarding drought. Drought research is much more advanced in India but it is focused mainly on the arid and semi-arid zones. There are no major agencies conducting in-depth analysis of the nature and impact of drought in the sub-humid zone. Establishment of such agencies and linking them up with organizations involved in drought management at various levels would improve the overall drought management.

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 (Hazell et al., 1986), innovative approaches such as rainfall lotteries and international re-insurance of agricultural risks can provide promising opportunities (Walker and Ryan, 1990; Gautam et al., 1994; Skees et al., 1999; Turvey, 2001; WB, 2003; Glauber, 2004). However, these alternative schemes have not yet been adequately evaluated. There are important challenges in employing the weather risk markets in developing countries (Varangis, 2002; Skees et al., 2001). More work is needed for developing and pilot testing new types of insurance products and schemes suited to hundreds of millions of small farmers of Asia who grow rice primarily for subsistence.

Concluding remarks

Even in sub-humid 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. This is clearly an inadequate response for longer-term drought mitigation. Given the clear linkage between drought and poverty, it is critically important to include drought mitigation as an integral part of the rural development strategy. Policies that in general increase the 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 drought physiology 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 under-invested in developing countries of Asia. This is a cause for concern, not only for drought mitigation, but for promoting an overall agricultural development.

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Table 1. General characteristics, three countries.

Characteristics	China	India	Thailand
Per capita GNI (\$)	1290	620	2540
Pop'n below poverty line (%)	10	25	10
Pop'n of study area (million) ^a	155	88	21
Average landholding (ha/hh)	1.48	1.4	2.3
Share of agriculture to total GDP (%)	14	25	9
Share of agriculture to total employment (%)	49	60	49
Irrigated rice area (% of total rice area)	93	50	20
Rice yield (t/ha) ^b	6.2	2.9	2.6
CV of rice production (%) ^c	5	18	10
Share to world rice production (%)	30	21	4
Annual rainfall (mm)	1200-1400	1000-1300	1100-1500

^aThis refers to the total population of the provinces/states included in this study.

^bRice yield was estimated using 2002-04 data, for the whole country.

^cCoefficient of variations (CV) was estimated using 1970-03 data for the provinces/states included in this study.

Data sources: FAOSTAT data, 2005; WB, 2005; CIA World Fact Book, 2005; and IRRI, 2005.

Table 2. Description of secondary data used in the study, three countries.

Country	Province/ state/zone ^a	Number of selected county/district/province ^b	Data period Covered ^c
China	Guangxi	10	1982-2001
	Hubei	10	1982-2001
	Zhejiang	10	1982-2001
India	Chattisgarh	7	1970-2002
	Jharkhand	6	1970-1999
	Orissa	13	1970-2002
Thailand	Zone 1	6	1970-2002
	Zone 2	8	1970-2002
	Zone 3	2	1970-2002

^a Province, State, and agro-ecological Zone at the aggregate level and County, District, and Province at the disaggregate level were utilized for this study in China, India, and Thailand, respectively.

^b Geographical size of province in northeast Thailand was almost similar to the size of districts in India. Over time old districts/provinces were partitioned into new districts/provinces due to various administrative and/or political needs. This created a problem of constructing a consistent time series database. This problem was handled by integrating the database of new districts/provinces into old districts/provinces. Thus, all the analysis in this study was based on the old districts/provinces that existed in 1970.

^c In some cases, recent data was available at the aggregate level only. So, data up to the year 2003 was used at the aggregate level analysis in some cases.

Table 3. Sample selection schemes for farm household survey, three countries.

Country	Province/ State/ Zone	County/ District/ Province	Township/ Block/ District	Selected Village	Number of households surveyed (no)	Representative year	
						Normal	Drought
China	Guangxi	Nandan	Dongjin	Heli	30	2001	2000
			Huopai	Huopai	30	2001	2000
	Hubei	Xiangyang	Yuli	Yuli	31	2001	1999
			Baxu	Baxu	31	2001	1996
	Zhejiang	Qingyuan	Hedi	Hedi	31	2001	NA
India	Chattisgarh	Kanker	Kanker	Echhapur, Aturgaon, Sigarbhat, Pidhapal	100	1999	2002
		Mandla	Mandla	Malimohgaon, Dhauranala, Manadai, Khapakala	100	1999	2002
		Raipur	Bhatapara	Tarenga, Datarangi, Kadar, Khamariya	100	1999	2002
	Jharkhand	Palamau	Chandwa, Daltonganj	Bhusaria, Sinkaru, Atre, Chetar	78	2001	2000
		Santhal Parganas	Boarijore, Jarmundi	Sitalpur, Satiari, Baramra, Baratelo	98	2001	2000
		Singhbhum	Patamda, Tonto	Shukla, Phuljharma, Dokata, Daudanga	103	2001	2000
	Orissa	Bolangir	Patnagarh	Dampal, Chindaguda	97	2001	2002
		Dhenkanal	Odapada	Jogimunda, Jambahal	98	2001	2002
		Nuapada	Khariar	Gundichapara, Haripur	89	2001	2002
Thailand	Zone 1	Nong Khai	Fao Rai	Noan Meechai	20	2000	1999
		Ubon Ratchathani	Sawang Weerawong	Nong Kaen Pattana	20	2001	1996
	Zone 2	Buriram	Krasang	Ang Kruang	20	1998	2000
		Khon Kaen	Nong Rue	Fang	20	2001	1998
		Loei	Phu Rue	Lad Kang	20	1999	2001
		Maha Sarakham	Kosum Phisai	Yang Sinchai	20	1999	2001
		Nong Bua Lamphu	Sibun Rueng	Pa Ka	20	2001	1999
		Roi Et	Kaset Visai	Noi Pattana	20	2000	2001
		Udon Thani	Kumpa Wapi	Noan Hin Lad	20	2001	2000
	Zone 3	Chaiyaphum	Chaturat	Kroak Pak Warn	20	2000	2001
			Kaset Somboon	Pi Puay	20	2001	1999
		Khon Kaen	Wangnoi	Nong Ko	20	2001	2000
		Nakhon Ratchasima	Dan Khuntot	Don	20	2000	1998
			Kang Sanamnang	Noan Rawieng	20	2000	2001
			Khonburi	Noan Klang	20	2000	1997

Table 4. Coefficient of variation of rice area, yield, and production, three countries, 1970-2003.

Rice	Southern China	Eastern India	Northeast Thailand
Area	3	2	7
Yield	4	17	9
Production	5	18	10

Coefficient of variations are estimated based on secondary data of study provinces/states.

Coefficients of variations for China are estimated using quadratically de-trended data.

Coefficients of variations for India and Thailand are estimated using linearly de-trended data.

Data sources:

China: NBS, 2005.

India: NCAP-IRRI eastern India rice database, 2002 and INDIAAGRISTAT data, 2005.

Thailand: OAE, 2004.

Table 5. Estimated value of crop production loss due to drought using rainfall-based drought year, 1970-2002.

Country ^a	Drought years			Annual	
	Quantity	Value	Ratio of loss	Value	Ratio of loss
	of rice	of crop	to average	of crop	to average
	production	production	value of	production	value of
	loss	loss ^b	production	loss ^b	production
	(million t)	(million US\$)	(%)	(million \$)	(%)
Southern China	1.2	133	3	16	0.4
Eastern India	5.4	856 ***	36	162	6.8
Northeast Thailand	0.7	85 *	10	10	1.2

^aThe values are estimated based on secondary data of study provinces/states.

^b The value of production loss is estimated using both rice and non-rice crops for India while only rice crop is used for China and Thailand.

* $p < 0.1$ and *** $p < 0.01$.

Data sources:

China: NBS, 2005.

India: NCAP-IRRI eastern India rice database, 2002 and INDIAAGRISTAT data, 2005.

Thailand: OAE, 2004.

Table 6. Average income per household (US\$) in normal and drought year, three states, eastern India.

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

^a CH-Chattisgarh, JH-Jharkhand, and OR-Orissa.

^b Small animals include goat, sheep, chicken, ducks, calves, kids, and animal produce like milk, ghee, egg etc.

^c Others include sale of fruits, sale of fish, old age pension, small petty business, small artisan work and so on.

^d Livestock includes large animals like cattle, buffalo, bullock, and pig.

^e Major assets include land and building.

^f Minor assets include farm implements, jewelry and other small assets.

Table 7. Incidence of rural poverty among sample households in normal and drought year, eastern India.

States in eastern India	National estimate of rural poverty ratio ^a	Sample estimate of poverty ratio ^b		Percentage point increase (% point)	Number of people falling back into poverty (million)
	(%)	Normal year	Drought year		
Chattisgarh	37	43	76	33	5.5
Jharkhand	44	57	69	12	2.5
Orissa	48	54	70	16	5.0

^a Poverty ratio for Chattisgarh and Jharkhand are based on values for undivided states of Madhya Pradesh and Bihar, respectively. The national poverty ratio value is based on estimate during 1999-2000.

^b Monthly rural poverty line income of Rs 311.34, 333.07, 323.92 was used to define poverty line for Chattisgarh, Jharkhand, and Orissa, respectively.

Data source: Planning Commission, 2002.

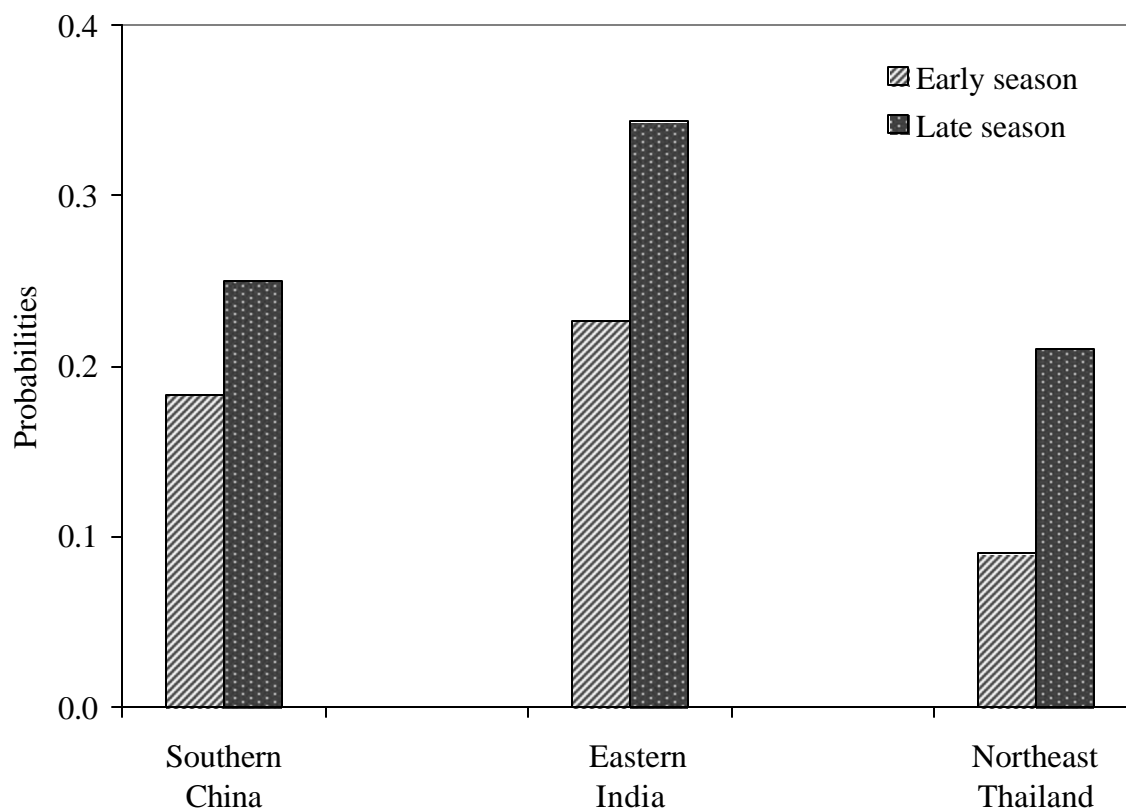


Figure 1. Estimated probabilities of early and late season drought, in southern China (1982-2001), eastern India (1970-2000), and northeast Thailand (1970-2002).

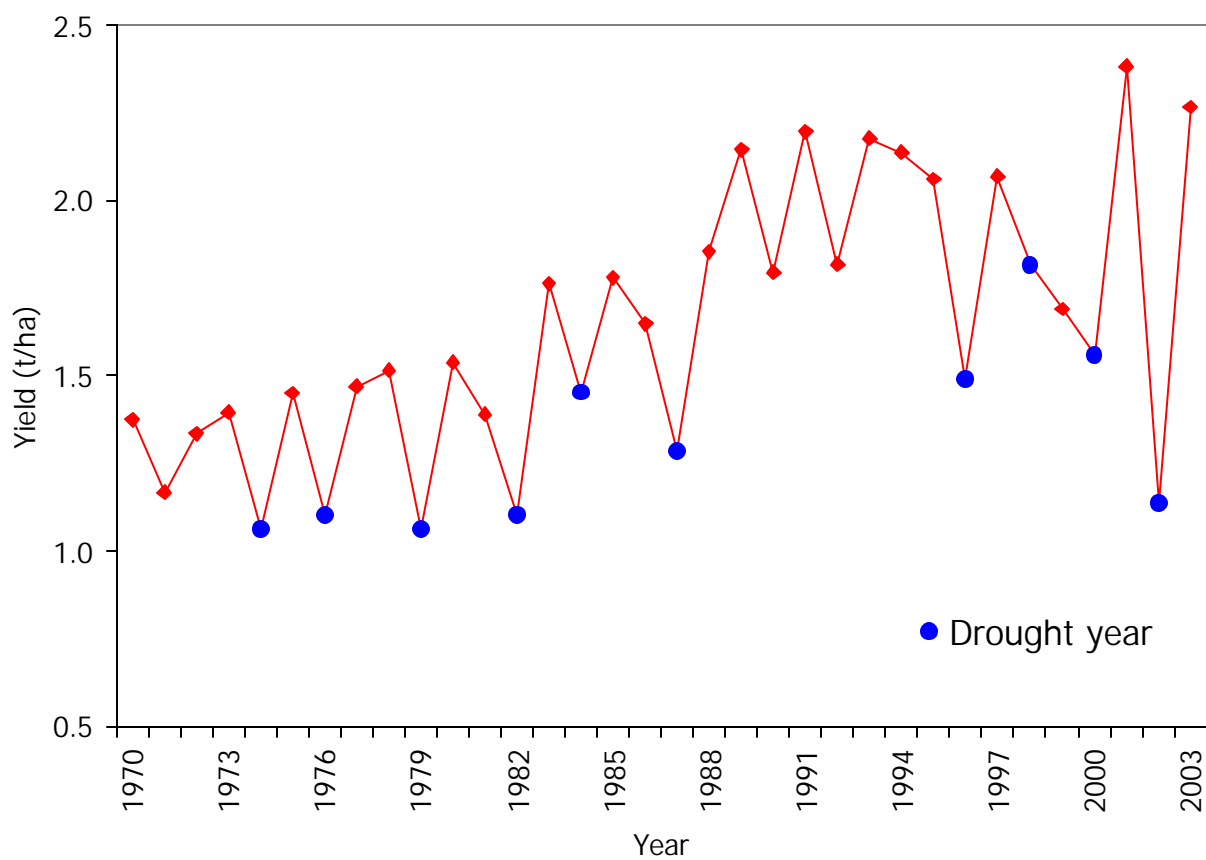


Figure 2. Trends in rice yield and major drought years, eastern India (Orissa), 1970-2003.

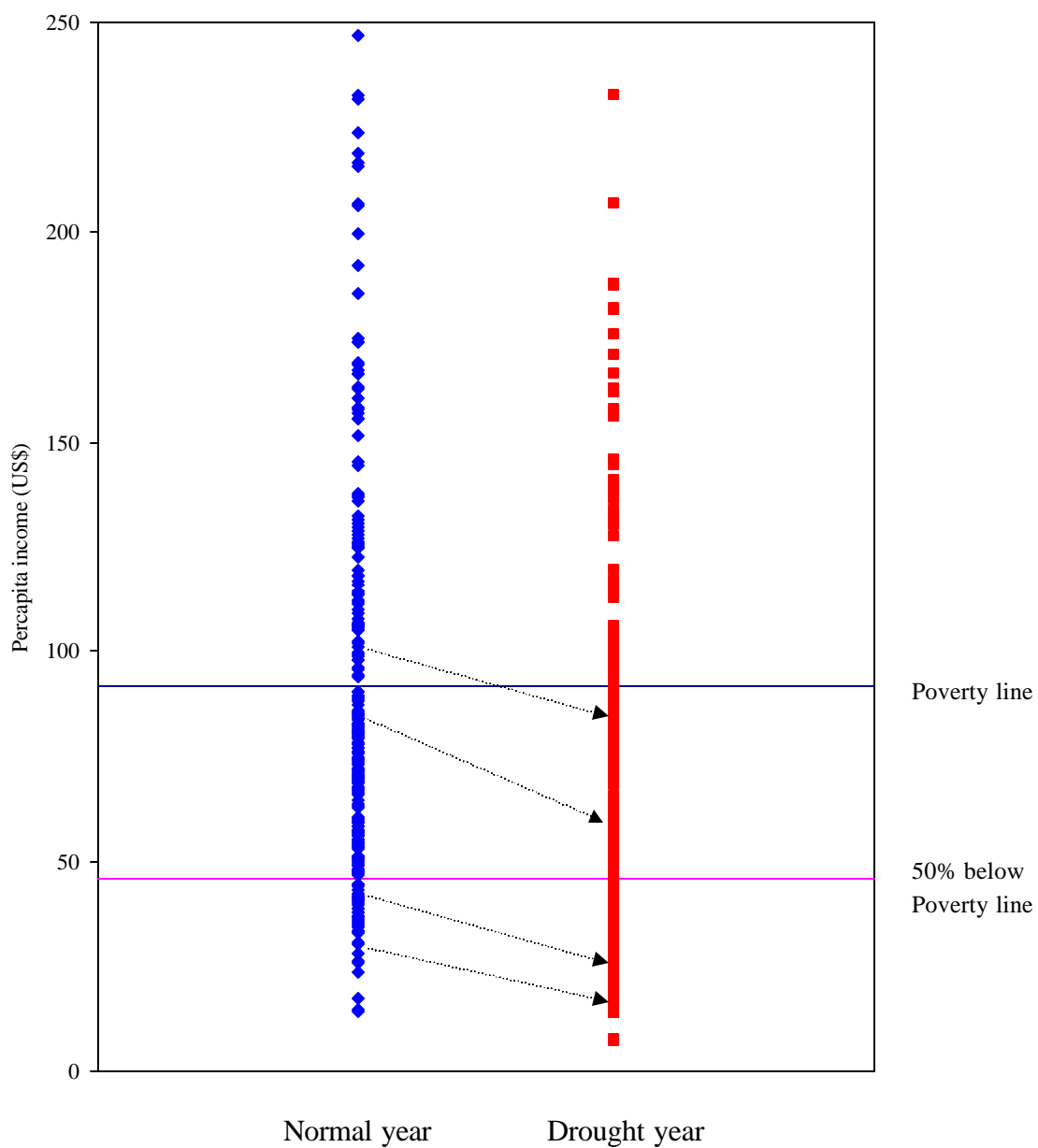


Figure 3. Effect of drought on incidence and severity of poverty phenomenon, Jharkhand (Each dot represents a household).

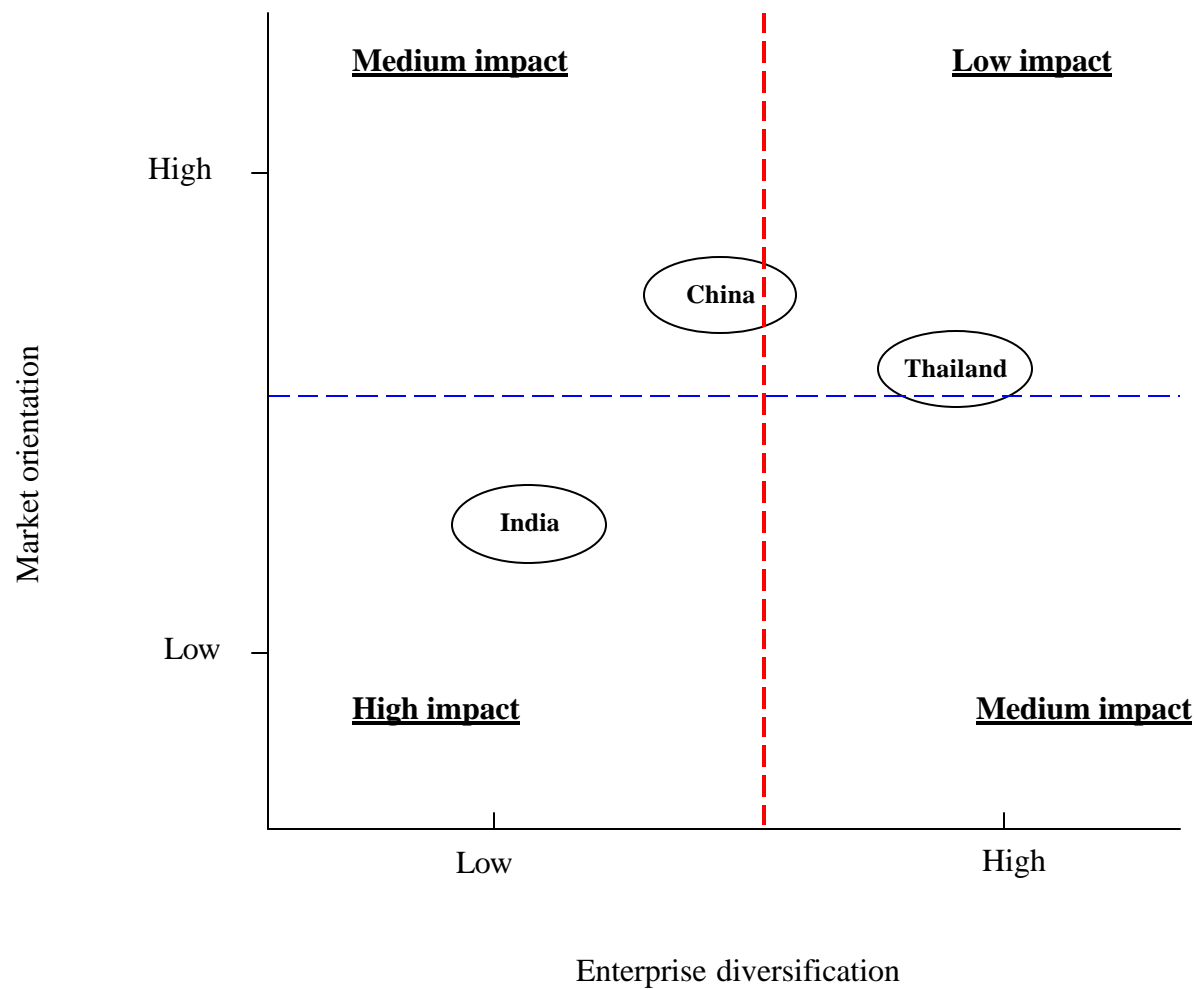


Figure 4. Household-level impact of drought.