ECONOMIC COSTS OF DROUGH AND RICE FARMERS' RISK COPING MECHANISMS: A CROSS COUNTRY COMPARATIVE ANALYSIS

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Short Summary

The economic costs of drought and rice farmers´ coping mechanisms are analyzed using time series and farm survey data from China, India and Thailand. The economic cost was estimated to be 2-6% of the value of output. Farmers´ coping mechanisms were found to be inadequate in preventing consumption shortfall.

Introduction

Agricultural production worldwide is subject to various risks of which climatic risks tend to be dominant, especially under rainfed conditions. Drought is an important and recurring climatic risk that has received a lot of public attention, especially because it often results in severe economic hardship to farmers. It can result in transient or even chronic poverty (Morduch). When farmers are very poor, such as often is the case in many developing countries, the consequences can be quite serious and may even lead to famine and death.

Due to the absence of efficient market-based mechanisms for diffusing risk, farmers have, over time, developed a range of strategies or coping mechanisms to provide "self-insurance". These coping mechanisms may or may not be providing adequate protection to the farmers, depending on the circumstance. Farmers' coping mechanisms could also be expensive in terms of implicit premium paid. It is essential to develop an in-depth understanding of current coping strategies so that technological, institutional and policy interventions that improve the overall efficiency by complementing/substituting farmers' strategies can be developed. It is recognized that farmers' coping mechanisms are not static but evolve over time, with farmers discarding strategies that are no longer relevant in the changed circumstances and evolving the new ones which are more suitable.

The main objective of this paper is to estimate the economic cost of drought and document the risk-coping mechanisms of farmers in drought-prone rice-growing areas of Asia. Much of the current literature on drought is focused mainly on arid and semi-arid zones (Campbell; Hazell, Oram, and Chaherli; Shivakumar and Kerbart). Due to low rainfall, these zones are highly drought-prone. Despite higher rainfall, droughts do occur frequently in the sub-humid zones of Asia where rice, wheat and maize are the major food crops grown. Yet, the impact of drought in the sub-humid belt on farmers' welfare and how farmers attempt to cope with these droughts have not been adequately analyzed. The aim of the paper is to contribute towards filling this knowledge gap.

The paper is organized as follows. A brief overview of farmers' risk-coping mechanisms are first provided. A short description of the methodology used and the salient features of agricultural production systems of the study region are subsequently presented. The empirical section is followed by a discussion of intervention opportunities for improving the management of drought.

Coping mechanisms

Income smoothing and consumption smoothing are the two major risk-coping strategies (Morduch). Income-smoothing strategies help reduce the fluctuations in income and are often known as ex-ante strategies. Income variability is reduced by the usual risk pooling and risk-sharing mechanisms. These include crop and income diversification, flexible management of inputs, and tactical adjustments during the growing season. These strategies are implemented prior to the full resolution of uncertainty and can be costly in terms of forgone opportunities for income gains as farmers select safer but low-return activities.

Consumption smoothing, or ex-post strategies, are designed to prevent shortfall in consumption even when farmers may have incurred income losses. These strategies include migration for wage employment, consumption loans, asset liquidation, and charity. Consumption shortfall can occur despite ex-post strategies if the drop in income is substantial. While it is convenient to consider income and consumption smoothing separately, in reality, they substitute for each other and hence, need to be considered simultaneously (Morduch). Existing literature indicates that poor farmers in Asia and Africa use these mechanisms to different extent, depending on their production environment, technology choices, and income levels (Reardon, Malton, and Delgado; Jodha 1991; McGregor; Umamaheswari, Krishnamoorthy, Nasurudeen, and Kolli; and Owens, Hoddinoot, and Kinsey).

Methodology

A comparative analysis of rice production systems in eastern India, south-central China, and northeastern Thailand is conducted. These three regions representing the three countries have differences in agroclimatic conditions, extent of irrigation, per capita income levels, levels of agricultural productivity and the institutional set-up for agriculture (Table 1). Thus, this cross-country comparative framework is designed to provide insights into the differences in the cost of drought and drought coping mechanisms resulting from these different initial conditions.

Characterization of drought is based on monthly rainfall data at various spatial scales. In China, analysis was done at the provincial and county level. In India, district and state level data were analyzed while in Thailand, the analysis was done mainly at the zonal and provincial levels. Data availability constrained the selection of the same spatial unit in all countries.

Table 1. Selected economic indicators for China, India, and Thailand

Characteristics	Unit	China	India	Thailand
Per capita GNP	US$	940	480	1980
Average land holding	ha/hh	1.48	1.4	2.3
Agriculture share to total GDP	%	15	25	11
Rice area irrigated	%	93	50	20
Rice yield	tons/ha	6.2	3.0	2.7
CV of rice production	%	5.0	14.0	10.0

Note: Coefficients of Variation (CVs) are for the provinces/states included in this study.

Production losses from drought were estimated through regression of temporal data on production and drought events. The responses of production, area and yield with respect to rainfall were also estimated.

In addition to the analysis of these secondary temporal data, farm surveys were conducted to measure the economic consequences of drought, identify various coping mechanisms and determine their overall effectiveness. The consequences of drought and coping mechanisms were elicited by asking farmers to make a comparison of "normal" and drought years that they encountered in the recent past. A total of 1080 farmers in the three countries were included.

Drought characterization

Although there are various definitions of drought depending on the perspective taken, a simple definition based on rainfall during the growing season of rice is used in this paper. Drought is considered to have occurred in a particular year if, during the rice growing season, the deficit in rainfall from the long-term average is 20% or more. The 20% threshold is commonly used by meteorologists to identify drought events in all three countries. Soil moisture-based indicators of drought would have been superior, but calculation of such indicators requires detailed data on soil, rainfall, and evaporation at shorter time steps (days, weeks) and at higher level of spatial resolution for soil water modeling than employed here. Such an approach was considered to be beyond the scope of this paper.

Crop response to moisture deficit depends on the timing of deficit, not just on the total size of deficit during the growing season. The same magnitude of deficit during the reproductive phase can have a bigger impact on yield than during the vegetative growth phase. Drought during the planting period of rice would tend to reduce the area planted more than the yield where as drought during the reproductive phase manifests itself mainly in terms of yield reduction. For these reasons, estimates of drought probability were derived for three time periods during the rice growing season, viz., early, mid and terminal periods. The calendar dates corresponding to these periods for rice in the three countries were adjusted to reflect the local rice-growing season.

Using the monthly rainfall data, the probability of drought during these periods was estimated. For each period, the 20% deficit threshold was used to identify drought events. A limitation of this approach is that rainfall during these periods is assumed to be stochastically independent. This is a somewhat strong assumption, especially when the adjoining periods are considered. To avoid difficulties caused by the likely stochastic dependence, only the late season drought events are considered for analyzing the yield effect. In the case of rice, the late season drought is biologically the most critical in determining the yield (Fischer and Fukai).

The estimated probabilities of drought, as defined, for the three study regions are presented in Table 2. The probability of seasonal drought varies from 6-19% in China, 9-19% in India and 3-9% in Thailand. Overall, the probability of seasonal drought for rice is highest in India and lowest in Thailand. A similar picture is obtained when the terminal drought probabilities are examined. The probability of terminal drought is much higher than that for the early season drought in most cases.

Table 2. Estimated probabilities of drought, 1970-03

	China			India*			Thailand@		
Drought	Guangxi	Hubei	Zhejiang	CG	JH	Orissa	Zone I	Zone II	Zone III
Early	0.25	0.25	0.25	0.21	0.26	0.16	0.15	0.15	0.15
Mid	0.31	0.22	0.25	0.09	0.23	0.19	0.24	0.24	0.36
Terminal	0.22	0.31	0.28	0.38	0.32	0.29	0.15	0.24	0.15
Seasonal	0.13	0.19	0.06	0.09	0.13	0.19	0.06	0.03	0.09

Note: * CG-Chhattisgarh and JH-Jharkhand; @ The zone classification is based on rainfall with Zone I having the highest average rainfall and Zone III having the lowest rainfall in northeast Thailand (KKU-Ford Cropping System Project).

Drought events that are spatially covariate are more destabilizing than droughts affecting small pockets. Probability of covariate drought was estimated using the sub-regional data (Table 3). A drought event is defined to be covariate if it affects more than 50% of the districts at the same time. A large proportion of both the terminal and seasonal droughts are found to be highly covariate spatially.

Table 3. Percent of drought events that cover more than 50 percent of districts, 1970-03

	China			India			Thailand		
Drought	Guangxi	Hubei	Zhejiang	CG	JH	Orissa	Zone I	Zone II	Zone III
Terminal	100	100	50	100	90	100	60	88	80
Seasonal	100	100	-	100	100	83	50	100	67

Estimating production losses:

The aggregative nature of analysis in this paper and data limitations preclude the use of crop models or production functions for estimating the production losses due to drought. Instead, simple empirical models based on correlation of production with rainfall were used. Two approaches were used. First, a fixed-effects model was used by specifying drought as a dummy variable in a trend regression of output. The coefficient of dummy variable measures the production loss associated with drought averaged over all drought events. Second, the effect on production was decomposed into area and yield components by estimating the area and yield elasticity with respect to rainfall. A quadratic function with respect to rainfall was specified to allow for the possible negative effect of excessive rainfall. The models utilized were:

$$(1) \qquad P = a + b\,T + c\,D + u$$

Where, P is the production, T is the time trend, D is the drought dummy and u is the random error term with the usual OLS properties. In this, the coefficient 'c' measures the average effect of drought on production.

For estimating the elasticity, the following regression was used:

$$(2) \qquad Y = a + b\,T + c\,R + d\,R^2 + u$$

Where, Y represents yield or area depending on the case, and R represents rainfall. Elasticity of Y with respect to rainfall is estimated at the mean values. Note that, by definition, production elasticity is the sum of yield and area elasticities.

Model (1) was used separately for rice and the subsequent non-rice crops. The growth of post-rainy season non-rice crops depends mainly on the residual soil moisture. During drought years, the production of the non-rice crops that follow rice is also likely to be adversely affected due to the reduced level of residual soil moisture. The non-rice crops included in the estimation are pulses, oilseeds, maize and wheat. Only those crops and regions that produce statistically significant coefficients at the 5% level were used for estimating the losses due to drought. The average value of production loss over drought and non-drought years was obtained by using the required probability weights.

The results indicate that the effect on rice production in India during drought year varies from 24-41% of the value of output (Table 4). For non-rice crops, it varies between 19-34% of the value of output. The total loss for the three states of India is $728 million during drought years. The expected total annual loss is $112 million with the loss being in the range 2-6% of the value of the output for different states.

Table 4. Estimated value of crop production loss due to seasonal drought, India, 1970-02

	Rice			Non-rice			Total		
	CG	JH	Orissa	CG	JH	Orissa	CG	JH	Orissa
Drought Year									
Value (million US$)	154	109	261	37	14	153	191	123	414
Share to total output (%)	24	41	29	20	19	34	24	36	31
Annual									
Value (million US$)	14	14	50	3	2	29	17	16	79
Share to total output (%)	2	5	6	2	3	7	2	5	6

In the case of Thailand and China, none of the dummy variable coefficients at the regional/provincial level were statistically significant, although at the county (or district) levels, there were some significant coefficients. This implies that the effect of drought on production in these two countries is somewhat localized at the county or district levels and do not necessarily show up in the aggregate provincial level data. Based on the county and district-level analyses (not reported here), the average production loss in China and Thailand is estimated to be less than 2% of the county/provincial value. The estimated coefficient of variation of rice production indicates that in China and Thailand, rice production is generally more stable than in India (Table 1).

Table 5. Rainfall elasticity of rice area, production, and yield, 1970-02

Country	Region	Area	Production	Yield
China	Guangxi	0.04	0.01	-0.03
	Hubei	-0.03	-0.02	0.01
	Zhejiang	0.06	-0.05	-0.11
India	CG	0.02	**0.88**	**0.86**
	JH	**0.18**	**0.94**	**0.76**
	Orissa	**0.11**	**0.75**	**0.64**
Thailand	Zone I	0.11	**0.35**	0.24
	Zone II	0.22	**0.55**	0.33
	Zone III	0.13	**0.30**	**0.17**

Note: Bold figures indicate statistically significant values at 5% level.

The estimated production elasticity for India and Thailand are statistically significant but not so for China (Table 5). This is partly due to the fact that much of rice production in China occurs under irrigated conditions, even in the selected provinces. Production losses are apparent from the household-level analysis to be presented later when examining locations where production occurs mainly under rainfed conditions. But these are local effects that are not transmitted to the aggregate level.

The results for India indicate that yield effect accounts for over 85% of the total production effect. Although the area elasticity is positive and statistically significant in two states, yield reduction is the major effect of drought. The district-level analysis (not presented here) indicates that area effect, although lower than the yield effect everywhere, tends to be larger in districts where early season drought is frequent. This is to be expected as early season rain is critical for successful planting.

The area effects are statistically insignificant in Thailand. Note that the probability of early season drought in Thailand is also low (Table 2). Yield effects are also statistically insignificant in Zones I and II. Production elasticities in Thailand, although statistically significant, are substantially lower than that for India. Thus, the effect of a given magnitude of drought in rice production is much higher in India than in Thailand.

Effect on Employment:

Assuming that the employment elasticity of rice output is 0.6 (Bhalla), and 120 person-days per ha are need for rice, a 24% loss in production of rice during drought years in the three states of India will reduce the employment by 150 million person-days. The second-round effect of such a massive loss in employment can be expected to be large also. Assuming that at least 75% of the households need some form of relief and assuming a wage rate of $1/day, this will amount to the relief assistance of about $110 million during the drought years. This cost is many folds more than the current expenditure on agricultural research in these states.

Ex-ante coping mechanisms

Ex-ante coping mechanisms are typically understood to be tactical adjustments designed to reduce losses during drought years. According to the definition we have used earlier, some of these adjustments may actually be incorporated into the production system so that they do not appear generally to be a response to drought. Here, we first consider the nature of tactical adjustments made by rice farmers (Table 6).

In all three countries, a common response to drought is a reduction in area of rice planted. In China and Thailand, the average reduction in area among the sampled households is 10%. In the case of India, this reduction is slightly higher at around 17%. Area planted is reduced mainly when drought is early.

When examining the various tactical adjustments listed in Table 5, it is apparent that farmers in India use more of these mechanisms than in China or Thailand. The major mechanisms used by the Indian farmers are changes in rice establishment methods (a change from transplanting to direct seeding), delaying of sowing date, replanting/resowing, increase in the seeding rate, reduction in fertilizers and weeding, substitution of minor millets and pulses for rice and early planting of the post-rainy season crops or an increase in their area. Chinese and Thai farmers used these mechanisms sparingly. The reliance on ex-ante coping mechanisms to reduce the losses to drought in India is likely to be due to higher intensity/frequency of drought, a greater dominance of rice in agriculture, and the lower ability of farmers to achieve consumption smoothing in the event of loss.

Table 6. Ex-ante adjustments in rice production, 2004[1]

	Adjustment	China	India	Thailand
1.	Rice area	-	--	-
2.	CE	0	✓✓	✓
3.	Sowing date	✓✓	✓✓	✓
4.	Replanting/resowing	0	✓	✓
5.	Seeding rate	0	+	0
6.	Rice varieties	0	✓	0
7.	Fertilizer quantity	0	--	-
8.	Fertilizer timing	0	✓	0
9.	Manual weed control	0	--	0
10.	Herbicide	0	NA	--
11.	Crop substitution	✓	✓✓	✓
12.	Change in post-rice cropping	✓	✓✓	0

Note: [1] "-" means a decrease, "+" means an increase, "0" means no change and "✓" implies a qualitative change. Double marks imply a larger change while single marks imply a marginal change. "NA" implies "not available".

What kinds of changes have been captured in the nature of the production system itself? Knowing that droughts are regular phenomena that cannot be predicted accurately, farmers would have evolved conservative practices overtime that give them some safety even at the cost of a reduction in income during normal years. The cost of these conservative practices is the income forgone in the pursuit of safety. To estimate the cost, we would need to compare the current average income with what would have been obtained in a drought-proof situation. This would obviously require a realistic farm model to simulate the counterfactual. Such an exercise is beyond the scope of the paper but an approximate cost estimate can be obtained by comparing the net income of rice from fields that are drought-prone with those that are better endowed in terms of moisture availability. A first approximation of this is produced by comparing the rice yields in these two types of fields during normal years. The difference in yield between irrigated and rainfed field during normal years provides such an estimate. The estimate for the study locations in India is in the range of 0.5 – 1.2 t/ha. Taking the lower estimate of the range, the total opportunity cost of drought to farmers for these three states of India is approximately $150 million. This opportunity cost is in addition to the actual cost of production losses during drought estimated earlier.

Ex-post coping mechanisms

A range of consumption-smoothing strategies are deployed to reduce the effect of income loss on consumption. These basically involve the use of past savings, generation of additional wage income through migration, asset sale, borrowing, and reliance on public relief. The qualitative nature of these ex-post coping mechanisms is summarized in Table 7.

Table 7. Ex-post adjustments in rice production, 2004

	Adjustments	China	India	Thailand
1.	Asset Sale			
	Livestock	Not common	Common	Not common (farming mostly mechanized)
	Land	Not practiced	Common	Not common
2.	Migration	Not common	Common (and increasing)	Common
3.	Consumption loan	Not available	Not available	Available
4.	Food for work	Not practiced	A major practice	Not practiced

Many of these ex-post strategies are not practiced in China while in Thailand, migration is a common strategy, with locally provided consumption loan being used in some situations of scarcity. In both China and Thailand, rice accounts for a relatively small share of the total household income, agricultural production systems are diversified and wage earning opportunities are better relative to India. In addition, the intensity and the impact of drought in terms of production losses are lower in China and Thailand than in India. These differences in the nature of drought and the economic structure in China and Thailand relative to India result in a lower economic cost of drought and farmers are apparently able to achieve consumption smoothing through their internal means. In addition, rice markets in both these countries are well-integrated, so that any local shortfall would not trigger an appreciable price rise as rice is brought in from neighboring areas in response to shortage. As a result, consumption losses in China and Thailand during the drought years are minimal and are localized.

Table 8. Change in sourcewise income during drought years, 2004

	Adjustments	India	China	Thailand
1.	Total income decline	-17	NA	
2.	Rice	-59	NA	-50
3.	Non-rice	-80	NA	-19
4.	Wage income	+18	NA	
5.	Animal sale	+34	NA	
6.	Asset depletion	+9	NA	NA
7.	Borrowing	+30	NA	NA
8.	Forest product	+9	NA	NA

Note: NA: Not available. The required quantitative data were not fully collected during the study.

In the case of India, farmers use several strategies in an attempt to reduce the impact of production shortfall on consumption. During drought years, rice income decline by 59% and the non-rice income by as much as 80% (Table 8). In order to offset these income declines, additional incomes are generated from wage employment (18% more than during normal years), and the sale of forest products (9% more than during normal years). However, the additional income from these sources is not enough to compensate for the loss of crop income and farmers are forced to liquidate some of their assets including livestock (34% more than during normal years) and even borrow from informal markets (30% more than during normal years). Although affected households receive some income from various “food-for-work” programs, this is too small to make any significant difference.

The analysis of sub-state level data in India shows an important interaction between migration and the use of forest resources for coping with drought. In locations where farmers have access to productive forests, an important coping mechanism is to rely on forests to generate both income and additional food. Migration in such locations is less important than in others where forests are far away or are depleted. Thus forests and migration tend to substitute each other to certain extent as drought coping strategies.

While migration is a regular phenomenon in Indian villages even during normal years, there is a change in the pattern and timing of migration during drought years. Normally, migration occurs after rice is planted, farmers return to harvest and plant the post-rice crop and migrate again. During the drought years, migration is early and a high proportion of migrants do not return up until the rice planting season the following year. As a result, planting of post-rice crops during drought years is often constrained by the limited availability of labor. Hence, the production of post-rice crop as a drought coping mechanism is likely to be less effective in the presence of migration occurring early in the season.

Welfare consequences of coping mechanisms

The use of all of the above mechanisms is not adequate to compensate for the income shortfall. Consumption declines as a result. Reduction in consumption takes the form of fewer numbers of meals, smaller quantities consumed per meal and consumption of inferior quality food (such as broken grains, millets, roots and tubers, not normally consumed). The consumption of vitamins and protein-rich food such as vegetables and meat also decreases. The coping mechanisms currently available to farmers are thus simply inadequate to prevent a decrease in consumption during drought years.

The survey data for India indicates that the consumption of rice decreases by 20% during the drought years. The consumption of wheat, pulses and oilseeds also declines. Much of the burden of adjustment in consumption falls on small and marginal farmers who have low levels of consumption even during the normal years. Similarly, women and children are more disadvantaged than men who generally receive a higher priority in intra-household food allocation.

It is well-established that the livestock depletion-replenishment cycle puts many farmers at a disadvantage (Jodha 1978). The price of livestock collapses during drought years when there are many sellers but few buyers. The survey data show that livestock prices fall by as much as 50% during drought years. However, when the drought is over and farmers try to buy back the livestock, the collective demand pushes the prices up, making it harder to replenish the livestock in a timely manner. It has been found that even after three years following a major drought, only 50% of the farmers were able to replenish their livestock to the pre-drought level. This is not a big problem if livestock are kept merely as a store wealth, in which case, selling livestock is equivalent to withdrawing cash from the bank. However, bullocks that serve productive purposes such as plowing are some of the more common livestock sold. As a result, farm productivity is likely to be adversely affected until farmers are able replenish their livestock.

Migration, although providing a means of coping with drought, also can result in adverse long-term consequences. Unskilled migrants often end up taking low-paying but hard labor jobs in construction work such as stone-breaking. As a result of long working hours and poor nutrition, their health is often adversely affected. Most of the migrant laborers also end up living in temporary “ghettos” in the new place where the living conditions are often much worse than in their original villages. When the whole family migrates, the children are taken out of the school. While migration of this kind does provide a means for survival, this is achieved often at the cost of health, and the general social well-being.

Discussions and Implications

The analysis shows that drought is an important problem in the rice-growing regions of Asia, although its intensity and impact varies across countries and regions. In China, the frequency and intensity of drought is lower and droughts are less widespread than in Thailand and India. Due to higher intensity of land use, higher crop diversification and greater opportunities for wage employment in China and Thailand, farmers seem to be able to achieve a reasonable degree of consumption smoothing than in India. In the case of India, despite the use of a range of income-smoothing strategies, farmers are unable to achieve effective consumption smoothing through their available means. As a result, consumption shortfalls occur. Naturally, the poorer and the vulnerable groups suffer more as they lack adequate options for preventing consumption shortfall.

The direct production loss associated with drought was estimated to be 2-6% of the value of output in India. In addition to these actual losses, the cost of ex-ante coping mechanisms as reflected in the nature of production systems in drought-affected areas account for another 5-6% of the value of production. Thus the total loss due to drought is estimated to be in the order of 10-13% of the value of output (or about $200 million annually). In the case of China and Thailand, the production losses are not widespread for the effect to be picked up in the provincial level data, but the affected households do lose 20-30% of income during drought years.

The cost of ex-post coping mechanism, although not quantified in monetary terms in the paper, is also seems to be substantial for India. Strategies such as asset depletion, withdrawal of children from school, dislocation associated with migration, and excessive exploitation of common property resources result in adverse long-term economic and social consequences. The economic costs of relief operations are also very high and have been estimated to be of the order of several hundred million dollars, but these have not been found to be very effective due to poor targeting, delays in implementation and budgetary constraints (Hirway).

What can be done to help improve drought management more effectively? Although various institutional reforms that improve the access of poor to productive assets ranging from land reform, efficient credit market operation, education, and infrastructure development to promote diversification can be suggested, an important avenue is to directly manipulate crops and the growing environments to avoid/reduce moisture stress. Improvements in germplasm to allow crops to either escape drought or tolerate its yield-reducing effects is a promising area of research. Possibilities also exist for manipulating the crop environment through irrigation, better retention of available soil moisture, and improvement in plant's ability to better use the available soil moisture.

Although the past progress in developing drought-tolerant germplasm has been slow, the use of biotechnology tools such as gene mapping and market-aided selection provides a new opportunity for making substantial progress (Bennett). 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, various programs to augment moisture availability through watershed development (Rao) and through agronomic manipulation (Fukai, Cooper, and Salisbury) of crops hold much promise. It is important, however, to ensure that adequate research investments are being made at both the international and national level for technology development, given the huge economic and social costs of drought. A low research intensity in developing countries of Asia (Pal and Singh), however, suggests that the resource allocation may be sub-optimal.

Two other avenues of potential importance are designing new forms of agricultural insurance such as rainfall insurance (Gautam, Hazell, and Alderman) and improving drought-forecasting capabilities (Abedullah and Pandey). Both of these avenues that hold some promise have not been adequately investigated in the context of rice production systems of Asia.

Reference

Abedullah, and S. Pandey. “Risk and the value of rainfall forecast for rainfed rice in the Philippines”. *Philippine Journal of Crop Science* 23(1998): 159 - 165.

Bennett, J. “Biotechnology and the Future of Rice Production”. *Geojournal* 35(1995): 3350 - 0337.

Bhalla, S. “Trends in Employment in Indian Agriculture, Land, and Asset Distribution”. *Indian Journal of Agricultural Economics* 42(1987): 537 - 560.

Campbell, D. J. “ Response to Drought Among Farmers and Herders in Southern Kajiado District, Kenya: A Comparison of 1972-1976 and 1994-1995”. *Human Ecology* 27(1999): 377 - 416.

Fischer, K.S., and S. Fukai. “How Rice Responds To Drought”. *Breeding Rice for Drought-Prone Environments*. K. S. Fischer, R. Lafitte, S. Fukai, G. Atlin, and B. Hardy, ed., pp. 32 – 36. International Rice Research Institute, Los Banos, Philippines, 2003.

Fukai, S., Cooper, M., and J. Salisbury. “Breeding strategies for rainfed lowland rice in drought-prone environments”. Proceedings of an International workshop, Ubon Ratchathani, Thailand, 5-8 November 1996. Australian Center for International Agricultural Research, Canberra.

Gautam, G., Hazell, P., and H. Alderman. “Policy Demand for Drought Insurance”. Policy Research Working Paper 1383, Agriculture and Natural Resources Department and policy Research Department, The World Bank, Washington, D.C.

Hazell, P., Oram, P., and N. Chaherli. “Managing Droughts in the Low-Rainfall Areas of the Middle East and North Africa”. Discussion paper no. 78, Environment and Production Technology Division, International Food Policy Research Institute, Washington, U.S.A., 2001.

Hirway, I. “Vicious Circle of Droughts and Scarcity Works: Why not Break it?” *Indian Journal of Agricultural Economics* 56(2001): 708 - 721.

Jodha, N. S. “Drought Management - Farmers’ strategies and Their Policy Implications”. *Economic and Political Weekly* 26(1991): A98 - A104.

Jodha, N. S. “Effectiveness of Farmers’ Adjustment to Risk”. *Economic and Political Weekly* 13(1978): A38 - A48.

KKU-Ford Cropping System Project. “An agroecosystem analysis of Northeast Thailand”. Faculty of agriculture, Khon Kaen University, Khon Kaen, Thailand, 1982.

McGregor, J. “Climate Change and involuntary migrations for Food Security”. *Food Policy* 19(1994): 120 - 132.

Morduch, J. “Poverty and Vulnerability”. *American Economic Review* 84(1995): 221- 225.

Owens, T., Hoddinott, J., and B. Kinsey. “ Ex-Ante Actions and Ex-Post Public Responses to Drought Shocks: Evidence and Simulations from Zimbabwe”. *World Development* 31(2003): 1239 – 1255.

Pal, S. and A. Singh. “Agricultural Research and Extension in India: Institutional structure and investments”. Policy paper No. 7, National Center for Agriculture Economics and Policy Research, New Delhi, 1997.

Rao, C. H. H. *Agricultural Growth, Rural Poverty, and Environmental Degradation in India*. New Delhi: Oxford University Press, 1994.

Reardon, T., Malton, P. and C. Delgado. “Coping with Household-level Food Insecurity in Drought-affected Areas of Burkina Faso”. *World Development* 16(1988): 1065 - 1074.

Sivakumar, S., and E. Kerbart. “Drought, Sustenance, and Livelihoods. Akal Survey in Rajasthan”. *Economic and political weekly* 17(2004): 285 - 294.

Umamaheswari, L., Krishnamoorthy, P., Nasurudeen, P., and R. P. Kolli. “Patterns of Droughts and Survival Strategies of Farm Households in a Drought-Prone District in Tamil Nadu”. *Indian Journal of Agricultural Economics* 56(2001): 683 - 695.