An Open Access Journal published by ICRISAT

Vulnerability and Adaptation in Dryland Agriculture in India's SAT: Experiences from ICRISAT's Village-Level Studies

M C S Bantilan and K V Anupama

Background

This paper's contribution to the discussion on 'Adaptation to climate change for agricultural productivity'[1] stems from the knowledge generated from ICRISAT's long years of experience in research and micro-level interaction with farm households in the SAT through what are now well-known as the Village-Level Studies (VLS). These are panel data from a set of longitudinal surveys initiated by ICRISAT in 1975 in 10 Indian villages. The generation of this data was motivated by the challenge to understand the socioeconomic circumstances in which people in the rural economies of the SAT live, so as to devise strategies that will help reverse the trend of vulnerability, widespread poverty, and food insecurity. Extensive surveys were conducted to generate information that could inform policy of direct relevance to the most vulnerable people of the SAT. This paper presents insights into risk attitudes, coping mechanisms, and responses to public sector assistance in order to help households adjust to sources of vulnerability.

Sweeping changes have occurred in the village economies of the SAT since the last major VLS survey in 1985. Globalization of markets, rising population densities, diversification of rural incomes, degradation of arable land resources, changes in rainfall patterns resulting in persistent drought, and feminization of agriculture have had a tremendous impact. In view of these profound economic, social, and climatic changes, ICRISAT revisited the same villages last year with the objective of beginning a second generation of VLS featuring on-the-ground collection of information on farm households to assess the changes and the associated evolution of coping mechanisms and agricultural investment patterns. Such an assessment could provide valuable insights for future planning for agricultural and sustainable development. While this paper features observations from the 10-year panel data in India, it must be noted that ICRISAT resumed similar efforts in two locations in sub-Saharan Africa, i.e., Burkina Faso and Zimbabwe.

Changing Scenario in VLS Villages

Many important changes have taken place not only in the agroclimatic conditions but also in the socioeconomic situation of the farmers in VLS villages since 1989. The following is a summary of these trends.

Rainfall

Distribution of rainfall is uneven. Late monsoons and uneven distribution of rainfall at critical stages of crop growth have become common. It was reported that there are an average of three drought years in a five-year period. Groundwater availability has been affected by low rainfall and the increasing number of wells and bore wells. Farmers are deepening their wells to get water to irrigate crops.

Cropping Pattern

Farmers are losing interest in growing cereal crops such as sorghum and millet because of the poor yields, low market prices, and changes in consumer preferences. They now prefer to grow commercial crops such as sunflower, maize, cotton, soybean, sugarcane, and vegetables.

1. This paper was presented at the workshop on "Adaptation to climate change for agricultural productivity", 1-3 May 2002, Vigyan Bhavan, New Delhi, organized by the Government of India, United Nations Environment Programme (UNEP), and the Consultative Group on International Agricultural Research (CGIAR).

Marketing

Farmers are not getting remunerative prices for their produce. While input prices have doubled within a short period, the harvest prices for cereal crops, especially sorghum and millet, have not increased by even 10%.

Labor Shortage

The SAT villages are facing a severe labor shortage because:
- large numbers of people migrate to cities for off-farm employment;
- greater cultivation of commercial crops requires more labor;
- villagers now prefer to send their children to school rather than work; and
- availability of regular farm hands has declined.

Machinery

Mechanized farming has increased in all the villages. Many farmers now own tractors, threshers, and sprayers, which they also rent out.

Credit Facilities

In the past, loans for agriculture were available only from village moneylenders, who charged high interest rates. But now farmers can turn to cooperative societies and banks.

Characterization of Risk and Vulnerability

Vulnerability in dryland agriculture in the semi-arid tropics is distinguished by the high incidence of rainfall-related production risk. Its consequences range from slower diffusion of more profitable but riskier technologies to spatially diversified but more fragmented landholdings, and even to higher population growth rates to compensate for the absence of an income safety net outside the family. It can exact a heavy toll on human welfare, especially in regions like the Indian SAT, where rural financial markets are fragmented and do not allow households to save and borrow to smooth income variability, insurance markets are incomplete, and futures price markets are nonexistent or rudimentary (Walker and Ryan 1990).

Empirical research facilitated by the panel data from ICRISAT's Village-Level Studies enables a deeper understanding of the conditions under which risk and household vulnerability play a significant role in shaping human welfare. The detailed discussion presented in this paper includes the sources of income risk in dryland agriculture in India's SAT and a comparison with those found in more favorable irrigated production environments. The role of risk perceptions in influencing farmer adoption decisions is discussed along with the direct and indirect effects of risk aversion on technology change. Evidence on the effectiveness of risk management in the study villages is examined. Finally, VLS data is analyzed to reveal the effectiveness of public sector policy responses to production risk in dryland agriculture in India's SAT. The pros and cons of crop insurance are presented as an institutional innovation to reduce vulnerability by compensating for and mitigating production risk in SAT agriculture.

For the overwhelming majority of cultivator households in the SAT, the main source of vulnerability is conditioned by crop revenue risk. Production risk can occur due to uncertainty in rainfall, measured in terms of its quantum, fluctuations, and outliers. High rainfall uncertainty manifests itself in yield variability which significantly conditions uncertainty in crop revenue. High rainfall uncertainty also manifests itself in seasonal crop labor demand patterns which can change markedly from one year to the next. Net crop revenue risk was the most important source of income variability for most farm households. Net crop revenue risk depends on variability from six sources:

- input prices
- input levels
- sown area
- harvested area
- output price
- yield.

The relative importance of the last two factors has received more analytical scrutiny than variability in input prices, input levels, and sown area. Barah and Binswanger (1982) focused on this issue in India's SAT and partitioned gross revenue variability into price, yield, and price-yield interaction components.

Bidinger et al. (1991a,b) studied the economic, health, and nutritional consequences of a drought in the mid-1980s in Dokur, a representative village with better local water harvesting infrastructure where tank and well irrigation was common. Although the drought was very harsh, food grain price stability and widespread availability of consumption credit allowed villagers to maintain their consumption pattern of normal years. But due to lack of public works programs, laborers, particularly women workers, endured unemployment. The scarcity of clean water, compounded by a severe shortage of electricity, led to a sizable increase in water-related morbidity symptoms such as diarrhoea, eye infections, and scabies in the second year of the drought.

Alumira (2002) and Jodha (1975) made similar observations in their respective studies on Zimbabwe and Rajasthan (India), where conventional adjustment mechanisms were broadly grouped under five categories:

- Restructuring current farm activities to maximize effective availability of products (including a variety of salvage operations)
- Minimization of current commitments, through diminution, full or partial suspension, or cancellation of allocation of resources
- Disposal of inventories of domestically-produced goods as well as purchased goods stocked for some planned use such as marriage, etc.
- Sale or mortgage of assets
- Out-migration with animals, etc.

Out-migration and sale of assets are the main adjustment mechanisms followed by farmers in Rajasthan.

The lagged impact of drought, in terms of decreased production or productive capacity of individual farms when farmers fail to protect their production base during a drought year, is reflected in various ways.

- Due to loss, disposal or mortgage of a farmer's land and other assets during a drought period, he may become a tenant, sharecropper or laborer, thereby affecting production. Similarly, loss of draft power during a drought year, resulting in a fall in production due to noncultivation of cultivable area, may delay sowing in the following year. Adoption of less intensive methods of cultivation in

the following year/years despite adequate rainfall is another example of production loss due to a farmer's inability to protect his production resources during a drought.

- In the case of livestock enterprises, the production and growth losses following a farmer's failure to protect his animals during a drought are clearer. Loss of productive stock built up over a long period (a process dictated partly by biological factors in the case of home-bred stock) is a permanent loss of productive capacity of the enterprise. Nonconception due to underfeeding in a drought year leads to low calving rates in the following year and further reduces the production possibilities of the livestock enterprise. To this may be added the current losses due to reduced yield and shortened lactation periods of milking animals during a drought year (Jodha 1975).

Similar situations were observed in Zimbabwe (Alumira 2002). The major problems encountered by farmers in that country were:

- Loss of individuals in productive age groups due to HIV/AIDS
- Lack of health facilities as a consequence of drought
- Widespread hunger/poverty
- Water scarcity
- Unemployment and out-migration
- Poor access to markets
- Low soil fertility.

Widespread hunger, water scarcity, and out-migration were most commonly observed during the droughts experienced in 1992 and 2002.

Coping Mechanisms

Diversification of Income Sources

In the 1970s, farmers in India's semi-arid tropics were predominantly dependent on agriculture for their livelihood except those groups which followed their traditional caste occupations. In the 1980s, farm households were observed to gradually adopt a wider range of livelihood options. Climatic risk, especially the frequent, prolonged, and severe droughts in the 1980s, forced farmers to devise strategies to cope with the situation.

Using data collected by the Overseas Development Institute (ODI) survey on livelihood strategies in 2001, Figure 1 shows the major sources of income of respondent farmers in Aurepalle and Dokur villages in Mahbubnagar district of Andhra Pradesh.

In a study of the income diversification strategies employed by different types of households in the drought-prone village of Kezi in South Extension, Matabeleland in Zimbabwe (Figure 2), Alumira (2002) found that sources of income diversified to include remittances, caterpillars, bricks, petty trade, beer, and salaries in addition to income from crop and livestock production, which was the dominant source of income in earlier years.

Income Compensation and Informal Self-Insurance

How well households manage risk in India's SAT may be discerned from the effectiveness of informal and private means of self-insurance and coping mechanisms that have been observed in the study villages. These were studied for two situations: (1) severe and prolonged drought; and (2) a more

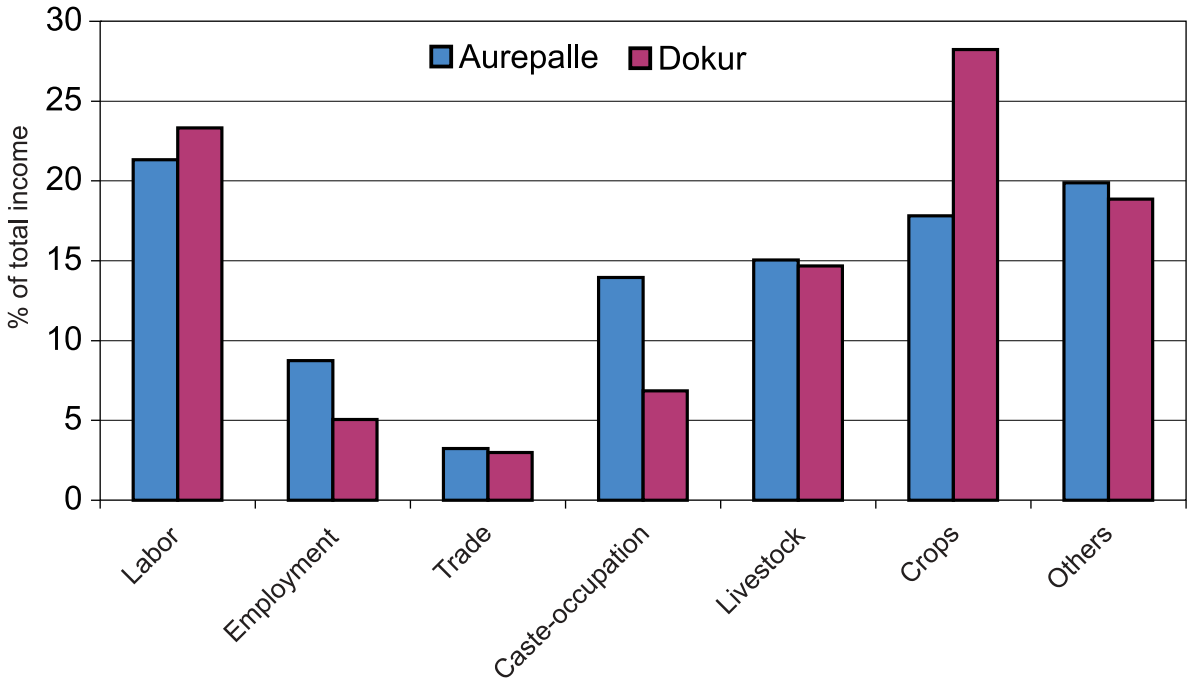
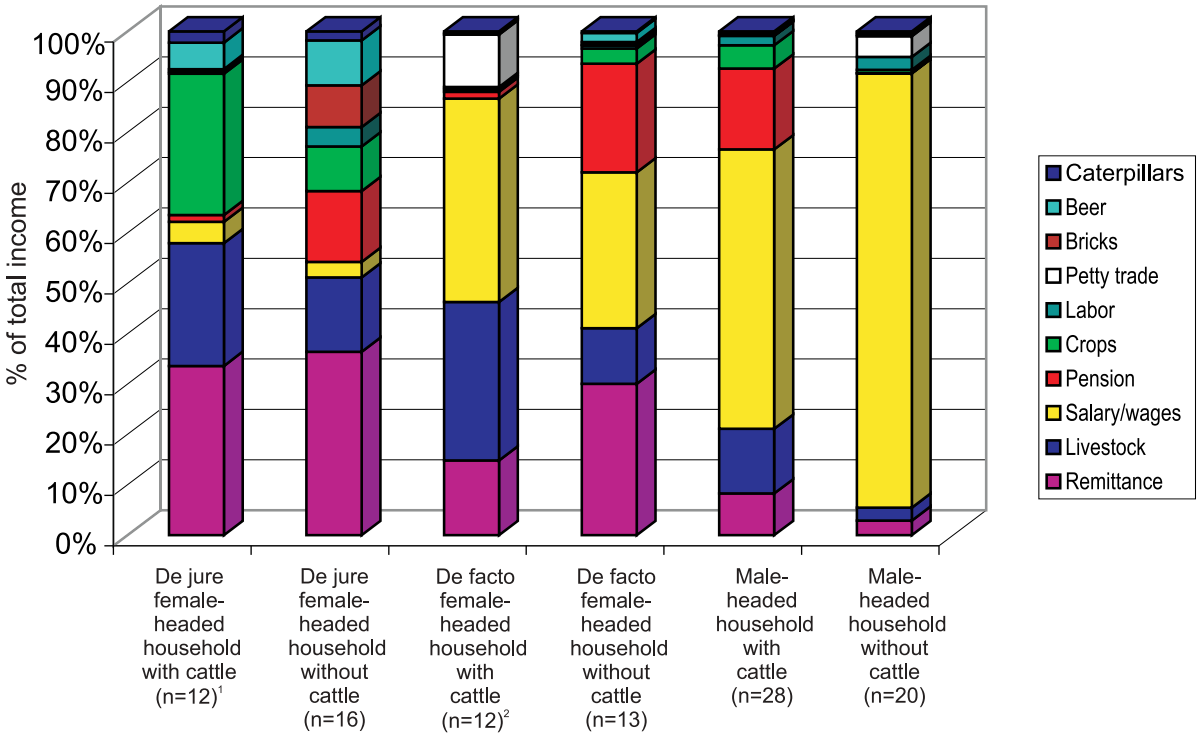


Figure 1. Sources of income of farmers in Aurepalle and Dokur villages in Mahbubnagar district, Andhra Pradesh, India, 2001.



1. Households headed by a single woman, unmarried, divorced or widowed.
2. Households in which the husband is not present and the wife is the main decision-maker in his absence.

Figure 2. Sources of annual cash income of diverse types of households (n = 101) in Kezi, Matabeleland, Zimbabwe, 2001.

normal course of events in which scanty or excess rainfall can lead to shortfalls in income but does not threaten subsistence (Walker and Ryan 1990).

During severe drought, effectiveness is measured by the ability of the household to protect consumption despite declines in income. Households in India's SAT have shown six ways to compensate for shortfalls in income. They can:

- borrow for consumption
- sell stored produce
- liquidate assets
- receive or transfer income from relatives
- change jobs and/or increase their labor market participation
- migrate in search of work.

It was noted that the importance of some of these forms of income compensation has diminished in the VLS study villages. For example, storage of foodgrains or fodder between cropping years is no longer predominant in the study villages. Appreciable amounts of paddy are carried over from year to year only by the largest farmers in the study villages in Mahbubnagar district of Andhra Pradesh, India. Transfer of income now plays only a minor role in dampening income volatility. Other coping mechanisms like asset liquidation and migration are used only as a last resort (Walker and Ryan 1990). Several empirical studies of household response to drought have shown that food consumption can decline substantially before the household parts with its assets or moves (Dreze 1988).

By far, the most heavily relied on means of compensating for shortfalls in income is borrowing for consumption in the informal credit market. Households in the study villages, especially Aurepalle, partially compensated for steep shortfalls in income by relying on consumption credit. The fairly localized but prolonged three-year drought in the mid-1980s in the Telangana region, where the two Mahbubnagar district study villages are located, precipitated a sharp rise in borrowing in the informal market in Dokur when the large village tank did not fill for rainy-season paddy cultivation for three consecutive years from 1985/86 to 1987/88 (Bidinger et al. 1991a,b).

Borrowing to maintain consumption is effective when risk is noncovariate, as many people do not borrow at the same time. Even during a drought year, the village credit market may be quite capable of financing a substantial amount of consumption credit without an appreciable change in the interest rate. For instance in the Dokur study, appreciable changes in interest rates were recorded only well into the second drought year. However, the village credit market is necessarily personal and spatially restricted; severe droughts over consecutive years eventually push interest rates up. As was observed in the well-irrigated villages of Mahbubnagar district, drought is also usually accompanied by an increase in demand for well deepening, digging, and in-well bore drilling. This increase in demand for investment credit places an additional strain on the informal village credit market (Walker and Ryan 1990).

Data from several microeconomic surveys have amply demonstrated how ineffective private means are in maintaining household food consumption in the face of a large covariate risk like a severe interregional drought. In a detailed study of famine and famine policies in Rajasthan, Jodha (1975) examined the validity of the criticism that the "administrators' lack of understanding of the true nature of the distress caused by drought or famine is responsible for too liberal, wasteful and devoid of economic rationality government policies". The detailed study of the 1962/63 drought in several villages of Rajasthan is illustrative and fairly representative of farmers' responses to and the consequences of severe drought in India's SAT. Crop and livestock income contributed negligibly to household sustenance income during the drought years, and traditional risk management methods did

little to protect these income sources. Most households, particularly small-farm ones, relied heavily on wages from public relief works. Large farm households compensated for the shortfall in agricultural income by selling assets, leading to spiraling prices. Sources of credit dried up as the share of borrowings in household income ranged only from 6% to 13%. The annual interest rate on borrowings increased from 15% to 23%. Compared to the year before the drought, foodgrain consumption per day per adult fell by about 14%. The price of pearl millet, the staple food, increased by about 60%, and milk prices rose by 280%. Prices of most assets fell sharply as households faced a buyer's market during the drought and a seller's market after it. The price of bullocks declined by 51%, dry cows by 80%, lactating cows by 48%, sheep by 60%, and bullock carts by 40%. Some assets retained their value better than others. The price of goats, which are more divisible and better acclimatized to drought than most other domestic livestock species, actually went up by about 24%. The drought also affected human capital formation, as 42% of the households withdrew their children from school. In fact, many households eventually migrated. Those who stayed behind lost more of their livestock than those who migrated.

Crop Management Strategies

In the face of severe covariate risk, as experienced during consecutive drought years, farm management methods are usually ineffective in preserving crop income. However, during normal years farmers have access to a number of measures that can partially smooth fluctuations in crop income (Walker and Jodha 1986). The two coping strategies that have received the most commentary and scrutiny in literature are crop diversification and intercropping.

Crop Diversification

Crop diversification is regarded as the most important weapon in a farmer's management arsenal to combat crop income risk, especially in developing countries where futures and insurance markets are not well developed. The VLS case studies present evidence of how diversification protects households from fluctuations in crop income.

The determinants of crop diversification varied substantially across the three VLS locations. In each region, it appeared to be a response to differential resource endowments. Draft power availability was an important explanation for variation in crop diversification across households within Mahbubnagar and Akola districts in peninsular India. Larger farms with more gross cropped area were more diversified than their smaller counterparts. This difference may be attributed to a more pronounced need to reduce peak season labor requirement, exploit the better potential of location-specific production opportunities associated with holding more fields, and greater access to credit to sow land to more input-intensive crops (Walker and Ryan 1990).

In Sholapur region, also in peninsular India, resource endowments were less important in explaining diversification. This may largely be accounted for by differences in land quality, cropping year conditions, and village disparities within the region. In particular, in response to low rainfall in June, July, and August and to more plentiful rain in September, postrainy-season sorghum accounted for 85% of the gross cropped area in Shirapur in 1977/78, when the diversification index fell dramatically (Walker and Ryan 1990).

The influence of irrigation was significant and also region-specific. In Mahbubnagar, widespread irrigation led to more specialization in paddy production; in dryland Akola and Sholapur, limited well irrigation, particularly in the postrainy season, opened up opportunities to grow a wider range of crops

such as wheat, lucerne, chickpea, and other pulses.

Most farmers are risk-averse and diversify their portfolio of cropping activities (Walker et al.1983). Risk preferences are swamped by interhousehold variations in resource endowments conditioning the level of crop diversification, and climatic effects such as rainfall at sowing time in drought-prone villages, as exemplified by Shirapur and Kalman (Walker et al. 1983). The level of crop diversification depended much more on farm size than on the degree of risk aversion within a farm-size group. Greater diversification by larger farms stemmed primarily from greater resource availability.

An analysis of VLS data from villages in Akola and Sholapur regions revealed that crop diversification appeared to be effective in imparting stability to the household crop income. At the margins, crop diversification was about three times more effective in stabilizing net returns in rainfall-assured Akola than in drought-prone Sholapur (Walker et al. 1983). It is not surprising that there is less scope for crop diversification to emerge as a successful self-insurance measure in the Mahbubnagar and Sholapur villages since most crops available here are vulnerable to one risk, drought. The greater diversity in potential yield reducers in the Akola villages in turn enhances the attractiveness of crop diversification as an effective means of self insurance for farm households (Walker et al. 1983). Largely, climatic differences are at play here. Higher rainfall/deeper soils in Akola and a rainfall pattern allowing rainy- or postrainy-season cropping in Sholapur allow more flexibility than the monomodal rainfall pattern and shallow/light soils in Mahbubnagar.

Intercropping

Row intercropping, and to a lesser extent mixed cropping are common in traditional farming systems in many regions that fall in India's SAT (Jodha 1981). Research shows that through more efficient use of nutrients, moisture, and light, yields from intercropping alternatives are often relatively higher than those from pure stands of the same species grown in proportional areas (Willey et al. 1987). This finding applies well to regions in the dry semi-arid tropics where there is seldom sufficient soil moisture to harvest heavy yields from two sequential crops but where sole cropping often fails to effectively exploit available resources. In contrast, evidence supporting the popular view in agronomic and economic literature (Papendick et al. 1976; Bliss 1976) that intercropping markedly reduces yield risk is less persuasive.

Two reasons are often cited for yields being less variable in intercropping systems:

- lower disease and insect pest incidence; and
- greater potential yield compensation (Willey 1981).

Although the generalization that intercropping usually reduces pest abundance mostly holds (Risch et al. 1983), counterfactuals are easy to find in biological science literature. These studies emphasize the extent to which pest and disease infestation are conditioned by location-specific interactions in complex cropping systems.

Yield compensation effects in intercropping systems are also location- and system-specific. Yield compensation is influenced by a crop's ability to take advantage of augmented light, nutrients, and/or soil moisture released by other crops that are adversely affected by sources of risk. If yield compensation was common, yield covariances between species would be less when they are sown in an intercropping system than when sown in pure stands. Like diversification, intercropping appears to be a response to physical resource endowments, particularly to the quality of those endowments (Singh and Jodha 1986).

Summing up, evidence seems to point to crop diversification and intercropping as being more effective in reducing crop income risk in the higher and more rainfall-reliable villages of Akola in

Maharashtra, India, than in the lower and more rainfall-variable villages of Mahbubnagar and Sholapur regions.

Public Policy Responses

Public sector assistance is needed to help households adjust to persistent drought. In fact, the effectiveness of household risk adjustment depends on both private- and public sector responses and their interaction.

One relevant though crude measure of the effectiveness of the private and public sectors' performance is in assisting households in managing famine risk centers to the extent that regionally covariate risks, comprising both natural and man-made disasters, compel farm households to sell land to meet current consumption expenses. Such transactions are usually labelled as distress sales, and are often viewed as a means to economic polarization (benefiting large holders at the expense of small farm households) in rural South Asia, where land is the dominant form of wealth, source of collateral, means of production, and determinant of status (Cain 1981).

Cain (1981) thoroughly analyzed the reasons for and the frequency and timing of land sales and purchases in Aurepalle, Kanzara, and Shirapur. He compared risk adjustment between these three Indian villages and a Bangladesh one. His research conclusively showed that the environment for managing risk was much harsher in the Bangladeshi village, where the bulk of land sale transactions engaged in by household heads from inheritance were made by landless, small-, and medium-sized farm households. Cain attributed the differences in risk management performance not only to more efficient rural financial markets but also to greater government investment in public works projects in the Indian study villages.

In the Bangladeshi village, usufruct mortgage was more prevalent, interest rates were considerably higher, and access to institutional credit was more limited. Property rights were also less secure. The government's response to the 1974 flood consisted primarily of food aid, which was not as readily accessible, and which did not appreciably deepen rural infrastructure as much as the employment opportunities generated by the crash relief works occasioned by the 1971-73 Maharashtra drought. The successful mitigation of the "never in a hundred years" drought in Maharashtra in the early 1970s is clearly one of the success stories in famine prevention in recent history (Dreze 1988).

Crop Insurance

Crop insurance is a contingency contract in which participant farmers pay premiums and collect indemnities when yields fall below an insured level. In India, as in most developing countries, crop insurance is commonly administered as crop credit insurance, where the insurer covers a percentage of the loan for annual cultivation expenses of the participant farmer. Repeated findings that relatively few farmers demand crop insurance unless voluntary programs are heavily subsidized are probably the best indication that benefits as perceived by farmers are small (Nieuwoldt and Bullock 1985; Gardner and Kramer 1986).

It can also be argued that farmers are reluctant to participate because they perceive crop insurance as ineffective in protecting households from crop income risk even in highly uncertain, dryland production environments typical of the SAT, where yield risk is often three to four orders of magnitude greater than price risk. Negligible risk benefits have been are estimated from simulated crop insurance designs carried out on data from households in Aurepalle, Shirapur, and Kanzara from 1975/76 to 1983/84 (Walker et al. 1986). The study results point to some general principles or conditions that

have to be fulfilled for crop insurance to generate sizable risk benefits. In particular, what defeats crop insurance in dryland agriculture is the recurring theme of area variability, which is largely conditioned by farmers' response to rainfall in the sowing season.

Crop insurance has been cited as the most direct policy response to address the problem of yield risk. Different risk perceptions are usually more influential in conditioning decision choices than divergent risk attitudes (Walker and Ryan 1990). Investments in activities that generate and diffuse more reliable technological information are probably more productive than alternative stabilization policies. All models of decision making under uncertainty, explicitly or implicitly include the twin concepts of risk perception and attitude. Perceptions are beliefs about what will happen if alternative courses of action are followed; the values people attach to those beliefs are reflected in attitudes. Risk has to be perceived for it to have the potential to influence adoption decisions. Sources of risk are also known to differ markedly from region to region depending on the wider spatial variations in agroclimatic and soil characteristics (Walker and Ryan 1990).

Rural Public Works and Other Rural Development Programs

Rural Public Works

Many rural development programs to improve the livelihoods of the rural poor have been implemented in Andhra Pradesh (India), Deb et al. (2002). A summary of some of these follows.

Title of the program	Focus	Highlights
Water conservation, drought, health	Issues related to health, drought, and water conservation	Involves extension activities of the agricultural department, distribution of input subsidy under drought, and identification of community land for plantation.
Pension schemes	Improving of pension schemes	These schemes are assisting vulnerable groups like the aged, disabled, and widowed.
Public Distribution System	Effectively targeting the program to make it pro-poor	This ensures food security for all groups requiring such assistance. Relief is provided to genuinely vulnerable groups by supplying them rice, sugar, and kerosene at subsidized rates.
Women's Self-Help Groups (SHGs)	Self-help movement through savings has been taken up by women.	The group's corpus consists of savings, government assistance, and bank loans. Members use the loan out of the group's corpus for their personal needs and income-generation activities. The SHGs are

Continued...

Table *continued...*

Title of the program	Focus	Highlights
		popularly called DWACRA (Development of Women and Children in Rural Areas) groups. Due to persistent government efforts, women have become very active and are concerned with issues relating to them and their surroundings.
Water user association (*Neeru, Meeru*)	Linkage between the irrigation department and farmers' bodies	Place the irrigation system on a sustainable basis by involving farmers in irrigation management. Expanding effective irrigated areas in existing systems. This process enabled farmers to acquire experience in undertaking maintenance works and comprehend the complexity of maintaining and operating irrigation systems.
National Family Benefit Scheme	To support a family when an earning member suddenly dies	Support a family with Rs 10000 when an earning member suddenly dies.

Consumption Credit

Consumption credit was observed to be the primary means of risk adjustment in households with shortfalls. Bidinger et al. (1991a,b) have illustrated how households maintain their consumption levels in the face of sharp shortfalls in income. This was studied by documenting the incidence of income shortfalls and how consumption was financed in households with shortfalls. In the second drought year, only 18% of the sample households had sufficient income to cover at least 75% of their consumption expenditure. The majority of households did not even have enough disposable income to meet 50% of their consumption expenditure. The 18 households which did not experience steep shortfalls in income in 1987 comprised mainly of farmers with larger landholdings who still had some water in their wells for irrigation, and of landless laborers who actively participated in longer term construction contracts. Shop owners and households with many labor market participants were also successful in maintaining income at levels exceeding or approaching their levels of consumption expenditure.

Food Price Stability and Subsidized Rice

The flatness of the prices of the main foodgrains, rice and sorghum, was perhaps the most remarkable feature of the mid-1980s drought in the Deccan plateau of peninsular India. The absence of sharply rising foodgrain prices attests to the somewhat localized nature of the drought and to a nationally integrated rice market responsive to spatial price variations (Bidinger et al. 1991a). It also proves the relative importance of irrigated cropland as the source of much of the foodgrain that enters the Indian market, with much of this irrigated area (e.g., Haryana and Punjab) being substantially less vulnerable to shortfalls in rainy-season precipitation than the villages included in ICRISAT's VLS.

Concluding Remarks

According to the Intergovernmental Panel on Climate Change (IPCC), the number of hungry and malnourished people in the world are expected to increase by about 10% later in the 21st century (IPCC 2001). This will be due to climate changes if no major adaptation program is undertaken. It is hoped that the insights shared from the micro-level VLS data from 10 villages in the Indian SAT will be useful in understanding, designing, and implementing long-term adaptations, taking into account evidence of adaptive capacity and coping mechanisms that have been evolved by those living in the fragile production environments of the SAT. More importantly, an understanding of micro-level coping mechanisms in these fragile environments will provide a people-oriented perspective on and social insights into the adaptation capacity of farmers so that policies may be effectively advanced to enhance this capacity.

Acknowledgments

The authors acknowledge the valuable inputs provided by S P Wani, N S Jodha, C T Hash, P D Bidinger, and Jane Alumira in improving this paper.

References

Alumira J D. 2002. Rural household investment behavior and implications for development pathways: a case study in the Semi-Arid Tropics of Zimbabwe. Presented at the CGIAR International Social Research Conference, 11-14 Sep 2002, Cali, Colombia.

Barah B C, and **Binswanger H P.** 1982. Regional effects of national stabilization policies: the case of India. Economics Program Progress Report no. 37. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 40 pp.

Bidinger P D, Walker T S, Sarkar B, Ram Murthy A, and **Babu P.** 1991. Consequences of mid-1980s drought: longitudinal evidence from Mahbubnagar. Economics Group Progress Report, Resource Management Program. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Bidinger P D, Walker T S, Sarkar B, Ram Murthy A, and **Babu P.** 1991. Consequences of mid-1980s drought: longitudinal evidence from Mahbubnagar. Economic and Political Weekly 26:A105-A114.

Bliss C J. 1976. Risk bearing in Indian agriculture. Presented at the seminar on Risk and uncertainty in agricultural development, 2-9 Mar 1976, International Centre for Maize and Wheat Improvement, El Batan, Mexico.

Cain M. 1981. Risk and insurance: Perspectives on fertility and agrarian change in India and Bangladesh. Population and Development Review 7(3):435-474.

Deb U K, Nageswara Rao G D, Mohan Rao Y, Johnson C, and **Farrington J.** 2002. Dynamics of livelihood options in Mahbubnagar village of Andhra Pradesh: 1975-2001, a draft report.

Dreze J. 1988. Famine prevention in India. Discussion Paper Series no. 3. Development Research Program, Suntory Toyota International Centre for Economics and Related Disciplines, London School of Economics. 108 pp.

Gardner B L, and **Kramer R A.** 1986. Experience with crop insurance programs in the United States. Pages 195-222 *in* Crop insurance for agricultural development: issues and experience (Hazell, P.B.R., Pomareda, C., and Valdes, A., eds.). Baltimore, USA: John Hopkins University Press.

IPCC (Intergovernmental Panel on Climate Change). 2001. Synthesis Report (Watson, R.T., and the Core Writing Team, eds.). IPCC, Geneva, Switzerland. Cambridge University Press. 184 pp.

Jodha N S. 1975. Famine and famine policies: some empirical evidence. Economic and Political Weekly 10(41):1609-1623.

Jodha N S. 1981. Yield stability and economics of intercropping in traditional farming systems. Pages 282-291 *in* proceedings of the International Workshop on Intercropping, 10-13 Jan 1979, ICRISAT Asia Center. Patancheru, Andhra Pradesh 502 324: International Crops Research Institute for the Semi-Arid Tropics.

Nieuwoldt W L, and **Bullock J B.** 1985. The demand for crop insurance. Presented at the 19th International Congress of Agricultural Economists, 26 Aug- 4 Sep 1985, Malaga, Spain.

Papendick R K, Sanchez P A, and **Triplett G B.** 1976. Multiple cropping. Madison, Wisconsin, USA: American Society of Agronomy. 40 pp.

Risch S J, Andow D, and **Altieri M A.** 1983. Agro-ecosystem diversity and pest control: data, tentative conclusions, and new research directions. Environmental Entomology 12:625-629.

Singh R P, and **Jodha N S.** 1986. Determinants of intercropping in Indian semi-arid tropics: causes and consequences. Economics Group Resource Management Program. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. Mimeo.

Walker T S, and **Jodha N S.** 1986. How small farm households adapt to risk. Pages 17-34 *in* Crop insurance for agricultural development: issues and experience (Hazell, P.B.R., Pomareda, C., and Valdes, A., eds.). Baltimore, USA: John Hopkins University Press.

Walker T S, and **Ryan J G.** 1990. Village and household economies in India's semi-arid tropics. Baltimore, USA: John Hopkins University Press. 394 pp.

Walker T S, Singh R P, and **Asokan M.** 1986. Risk benefits, crop insurance, and dryland agriculture. Economic and Political Weekly 21(25-26):A81-A88.

Walker T S, Singh R P, and **Jodha N S.** 1983. Dimensions of farm-level diversification in the semi-arid tropics of rural south India. Economics Program Progress Report no. 51. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 30 pp.

Willey R W. 1981. A scientific approach to intercropping research. Pages 4-14 *in* proceedings of the International Workshop on Intercropping, 10-13 Jan 1979, ICRISAT Asia Center. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Willey R W, Reddy M S, and **Natarajan M.** 1987. Findings from cropping systems research and pointers for alternative agricultural land use systems. Pages 155-164 *in* Alfisols in the semi-arid tropics: proceedings of the Consultants Workshop on the State of art and management alternatives for optimizing the productivity of SAT Alfisols and related soils, 1-3 Dec, 1983, ICRISAT Asia Center. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.