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**DIRECTIONS IN DEVELOPMENT**  
**Environment and Sustainable Development**

# Overcoming Drought

*Adaptation Strategies for  
Andhra Pradesh, India*



THE WORLD BANK



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## Foreword

Climate change is both an environment and a development issue. Any human-induced change in climate conditions will affect not just ecosystems and biodiversity, but will also affect agricultural productivity, water quantity and quality, human health, and human settlement patterns. All this has direct and potentially damaging implications for developing countries as it can, ultimately, undermine their aspirations of sustainable development.

Nowhere is this more critical than in India, where the poor are the most at risk from the increased variability and volatility in weather patterns. One of the key climate-related vulnerabilities of India's economy is its heavy dependence on the monsoons. Monsoon analysis reveals that some part or the other of the Indian subcontinent has been hit by drought almost every two years.

The disastrous effect of feeble or failed monsoons has been particularly acute in the state of Andhra Pradesh, where more than 70 percent of the people depend on agriculture for their livelihood. The potential for devastation has been tragically brought home to us by the suicides of thousands of farmers in recent drought years. And droughts will only get more frequent and more severe in the future as the climate changes in response to human activities.

The Government of Andhra Pradesh had requested World Bank assistance in helping the state adapt to climate change by integrating issues of climate variability into economic planning. This report is the product of collective research by the Bank and national experts to understand and quantify the drought risk that Andhra Pradesh faces. It seeks to help the state government develop anticipatory strategies for adapting to drought not just at the macro level, but also at the level of village communities and individual farms.

Developed after detailed consultations with a range of stakeholders, this report is a ground-breaking attempt to draw up a comprehensive drought management framework. It has been based on a probability model that brings together risk-mitigation and risk-financing techniques, and also considers the long-term impact of climate change. It has also led to a practical application on the ground, with the Government of Andhra Pradesh piloting an innovative Drought Adaptation Initiative with Bank support.

Michael Carter  
Country Director, India  
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The principal authors of this report are Kseniya Lvovsky, Olivier Mahul, Yuka Makino, Ian Noble, Adityam Krovvidi, Simon Francis, and Satya Priya.



## Acronyms and Abbreviations

AAL	average annual loss
ACFC	agricultural consumption of fixed capital
AGVA	agricultural sector gross value added
ANGRAU	Acharya NG Ranga Agricultural University
ELT	event loss table
EPC	exceedance probability curve
EPIC	Environment Policy Integrated Climate model
GCA	gross cultivated area
GCM	global climate model
GDP	gross domestic product
GFCE	Government final consumption expenditure
GFCF	gross fixed capital formation
GIA	gross irrigated area
GoAP	Government of Andhra Pradesh
GoI	Government of India
GrfA	gross rain-fed area
GSDP	gross state domestic product
GVA	gross value added
ha	hectare
I-O	Input-output

LCFC	livestock consumption of fixed capital
LEC	loss exceedance curve
LGVA	livestock sector gross value added
MT	metric ton
PML	probable maximum loss
RCM	regional climate models
SCFC	secondary sector consumption of fixed capital
SGVA	secondary sector gross value added
SPI	Standardized Precipitation Index
SUR	Seemingly Unrelated Regressions
TCFC	tertiary sector consumption of fixed capital
TGVA	tertiary sector gross value added
VOI	value of inputs
VOP	value of production
WXGEN	weather generator

# Executive Summary

Drought sets off a vicious cycle of socioeconomic impacts beginning with crop-yield failure, unemployment, erosion of assets, decrease in income, worsening of living conditions, poor nutrition, and, subsequently, decreased risk absorptive capacity, and thus increasing vulnerability of the poor to another drought and other shocks.

The mitigation of the impacts of drought has been a key area of focus of India since the 1950s, as evident through programs such as the Drought Prone Areas Programme, Desert Development Programme, National Watershed Management Programme for Rain-Fed Areas, National Calamity Contingency Fund, and the National Agricultural Crop Insurance Scheme. However, the human and social costs of droughts remain devastating.

Andhra Pradesh is one of the states in India that has historically been most severely affected by drought. The lack of monsoons has had a disastrous effect on the state's sizable agriculture sector and on a large share of the population dependent on agriculture for livelihood.

This study focuses on 8 (out of a total of 23) districts in Andhra Pradesh that are particularly vulnerable to drought: Anantapur, Chittoor, Cuddapah, and Kurnool in the Rayalaseema region; Rangareddi,

Mahbubnagar, and Nalgonda in the Teleangana region; and Prakasam in coastal Andhra. Together, these districts are home to about 30 million people and account for about 70 percent of the state's drought-related crop production loss. These districts also include some of the poorest areas and communities in the state.

The Government of Andhra Pradesh (GoAP) accords high priority to uplifting these areas, as demonstrated by the creation of a dedicated Department for Rain-Shadow Areas Development. While the GoAP continues to explore possibilities to increase areas under surface water irrigation and/or further develop groundwater resources, there are serious technical and economic constraints to increasing the volume of irrigation water for the majority of areas within these districts. Thus, there is a wide recognition in Andhra Pradesh of the need to complement these efforts with an adaptation process of a gradual shift to agricultural and economic practices that are more sustainable.

## **Study Objectives**

The objectives of the study were agreed through extensive consultation with several concerned GoAP departments (Environment, Disaster Management, Planning, Agriculture, Rural Development, Irrigation, and Rain-Shadow Areas Development) and other stakeholders so as to complement the existing state and Government of India (GoI) programs by enhancing the state's capacity to assess the long-term effects of drought and increase resilience at different spatial levels to drought risks.

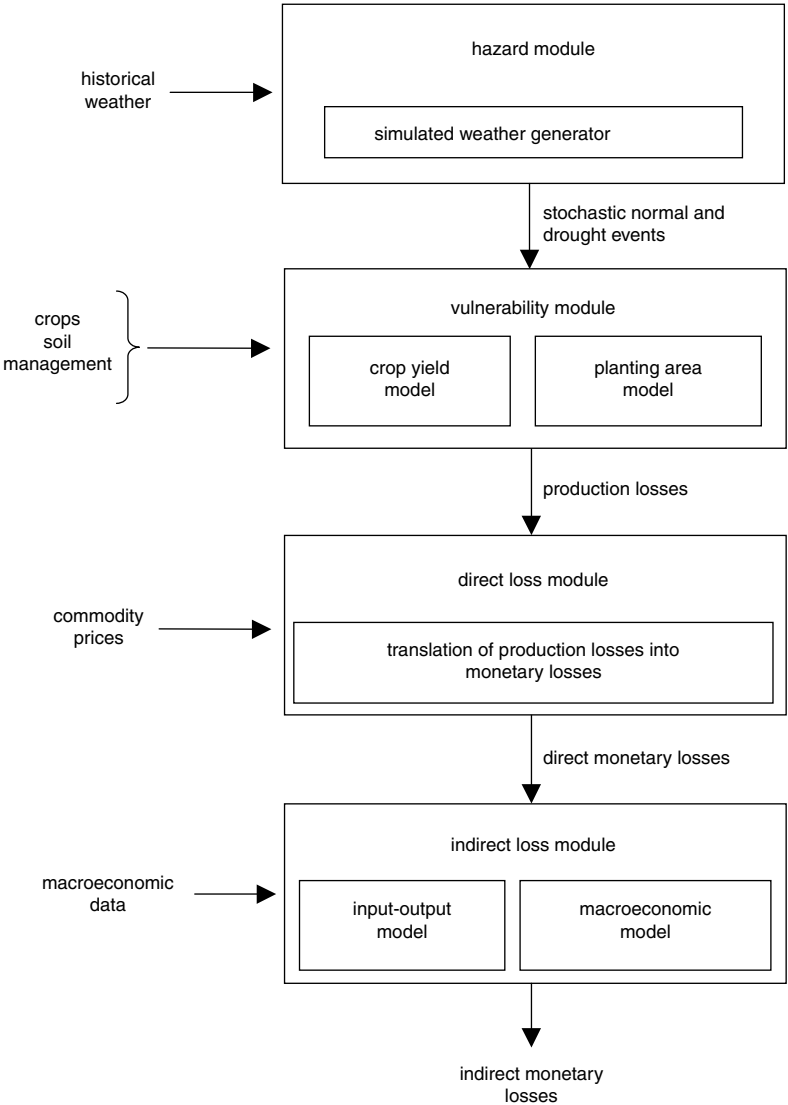
The study intended to (a) develop a robust analytical framework for simulating the long-term impacts of drought at the micro (drought-prone areas) and macro (state) levels, (b) conduct a quantitative probabilistic risk assessment of the impacts under different scenarios, and (c) assist the GoAP in the development of a forward-looking and anticipatory strategy for adapting to frequent drought events and water deficit conditions.

In addition to the macroeconomic and drought management scenarios, the development of the modeling framework aimed to account for the possible increase in frequency and severity of droughts that may occur owing to human-induced climate change. In this context, this study is linked to a larger program of work by the World Bank in a new strategic area on adaptation to climate variability and longer-term changes.

Methodology

The probabilistic drought risk assessment model developed for this study consisted of four modules, as described in figure S.1.

Figure S.1. Probabilistic Drought Risk Assessment Model



The model developed for this study is a powerful tool for thorough drought risk assessment (with statistical outputs, such as average annual loss [AAL] and loss exceedance curve [LEC]) and to investigate the impact of risk coping strategies and climate scenarios on crop yield and production in each block of the eight drought-prone districts. This model was calibrated using local experience in management practices and crop phenology in the eight selected districts. Its validation was very successful for the five major crops grown in these districts (that is, rice, maize, jowar (sorghum), sunflower, and groundnut).

The results presented in this report are aggregated to the district level, which is the smallest scale for which comprehensive validation data were available. Thus, the validation results do not provide a fair and full illustration of this model's capability to quantify the effect of drought and coping strategies on crop yield and production at the block level.

One of the particular challenges was in estimating the economic impacts of slow onset events, such as drought. Contrary to rapid onset disasters, droughts normally lack highly visible impacts; instead, their impacts are generally nonstructural and spread over long periods and large areas. Thus, though the approach broadly followed the general catastrophe risk-modeling framework used for assessing the impacts of rapid onset disasters (such as cyclones, floods, and earthquakes), it was customized to be applicable for slow onset events.

Droughts generate significant indirect losses as compared to direct losses in crop production. Indirect losses were estimated through a macroeconomic analysis and an input-output analysis. A critical task was to link drought risk analysis at the block level for the eight districts to the statewide macroeconomic analysis. A prototype macroeconomic model was developed to explain how the variability of the value of crop production in the eight selected districts affects the variability of the state gross value added (GVA) in the main economic sectors of Andhra Pradesh. The validation of the macroeconomic model was satisfactory, as the estimated agricultural GVA mirrored the observed agricultural GVA over the period of 1993–2002, especially during the drought years. The input-output model, the first ever developed for Andhra Pradesh, was used to provide details of the linkages between the different sectors and subsectors of the economy, the flow of goods and services, and employment.



## Key Findings

- Despite a variety of antidrought programs, the human and social costs of drought have been and remain devastating for the millions of people in Andhra Pradesh. Under the “business as usual” long-term scenario, the agricultural sector of these districts faces some loss in the value of crop production output for the five major crops combined, compared to a “normal” rainfall year, every second or third year (in other words, in 40 percent of all years). The AAL of output owing to the drought-prone climate is 5 percent for the eight districts. Individual farmers may suffer greater losses, and for many small and marginal farmers in these districts, a loss of output value of 10 or even 5 percentage points would mean falling below the poverty line. This suggests the need for enhancing an existing strategy by innovative, futuristic approaches and tools to help these people adapt to frequent droughts. The study findings highlight the importance of intensifying efforts to support economic and social development of drought-prone areas that are sustainable and resilient to water-scarce conditions in the long term.
- Impacts of droughts vary greatly across locations and crops depending on drought severity. For example, severe (once in 30 years) drought is likely to decrease rice yields from 29 percent in Nalgonda to 62 percent in Kurnool (table S.1). Yield losses of maize, a rain-fed crop, appear particularly staggering in Anantapur, Kurnool, and Mahbubnagar, which are the driest districts with less than 600 millimeters of rainfall every year. Importantly, different crops can be particularly vulnerable in different districts.
- In the situation of acute water deficit caused by a major drought, farmers often “rationalize” the use of available water by reducing an area under water-intensive rice in favor of less water-intensive crops. However, this is practiced as a temporary measure with the area of rice typically restored once the drought is over. Modeling results showed losses borne by farmers because of drought can be significantly decreased by adjustments in farming practices that reduce water

**Table S.1. Simulated Rice Yield Losses in Drought Years (Percent Normal Year)**

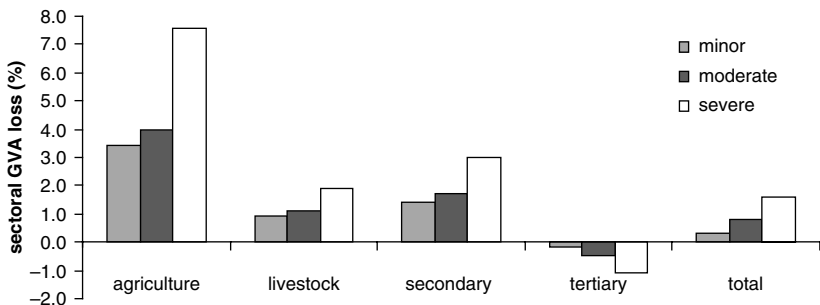
	<i>Anantapur</i>	<i>Mahbubnagar</i>	<i>Kurnool</i>	<i>Cuddapah</i>	<i>Chittoor</i>	<i>Prakasham</i>	<i>Rangareddy</i>	<i>Nalgonda</i>
Minor	14	10	13	11	10	10	19	8
Moderate	27	19	32	21	18	19	24	16
Severe	45	26	62	31	35	33	31	29

Source: Simulations by the model developed under this study.

demand, such as a permanent shift to a larger share of less water-intensive crops in the cropping mix. For example, in Anantapur this strategy can reduce by half the AAL of the overall crop production output during the drought years and increase the all-year average annual crop production output by one-third.

- The impacts of measures that can be adopted by farmers are highly location-specific. Reallocation of irrigation water was found to be much less effective in Mahbubnagar, where further change in the cropping mix is apparently needed. This suggests that there is a significant scope for increasing the effectiveness of advice to farmers about undertaking location-specific drought coping measures, such as switching to alternative crops in response to a poor monsoon.
- Global climate change is likely to further increase the benefits of shifting from rice to less water-intensive crops. Modeling of the longer-term impact of human-induced climate change undertaken by the study reinforces the need for shifting to less water-intensive activities in the drought-prone districts.
- Against the significant losses caused by drought to farmers and communities in drought-prone areas, the statewide macroeconomic impact is rather modest. The long-term AAL in GVA for the state caused by all drought events (averaged over a larger number of drought and nondrought years) is estimated at only 0.2 percent, even in the benchmark (business as usual) case (figure S.2). During the years of severe drought, the loss in total GVA increases to 1.6 percent. For sectors, the macroeconometric model shows a significant negative impact of drought on the agricultural sector, a much more limited impact on the livestock sector and the secondary sector (manufacturing), and a positive impact (with one year lag) on the tertiary sector (services). The livestock sector appears less affected by drought than the secondary sector, which is quite dependent on performance of the agriculture sector.
- The macroeconomic impact of drought is decreasing further because of the underlying structural changes in the Andhra Pradesh economy. The trend of the Andhra Pradesh economy since the 1980s has been a decrease in contribution by the most vulnerable agriculture sector against increasing contributions from the secondary and tertiary sectors. Because this trend is most likely to continue, the macroeconomic impact of drought will further decrease. The future impact of drought on the rural economy can be moderated because of the increasing role of the livestock sector. This is consistent with the analysis of historical data on past droughts, which revealed a decreasing impact trend on

**Figure S.2. Conditional Average Loss in GVA Owing to Drought (Percent), by Sector and Drought Category (Minor, Moderate, Severe)**



Source: Study model simulations.

Note: Positive numbers/percentages represent loss while negative numbers mean gains.

both the overall economy and the primary sector. The AAL caused by droughts on the Andhra Pradesh economy appears lower than that due to cyclones or floods, as was estimated by another World Bank study, although any comparison should be made with caution because the losses were not measured in the same units.

- Accelerating the structural shift in the economy from the agriculture sector to the secondary and particularly tertiary sectors can be interpreted as a powerful macroeconomic drought adaptation strategy. The impact of such a shift would be an 80 percentage point decrease in total GVA loss attributed to drought events when the shares of the agriculture, secondary, and tertiary sectors roughly approximate the structure of the economy of Brazil, as compared to the impact when maintaining the current structure of the Andhra Pradesh economy. This means that the loss in total GVA can be decreased from 1.6 to 0.2 percent under severe drought in the eight districts.
- The findings of a relatively small and declining macroeconomic impact of drought are consistent with a growing body of evidence on the macroeconomic impact of climate-related disaster. A recent study, which used worldwide historical data, showed that the maximum annual impact of drought is 0.8 percent of GDP for developing countries as a group.
- However, droughts continue to have a negative impact on the performance of the agriculture sector and, thus, the lives of the millions who depend on agriculture for livelihood, income, and employment. This highlights the need for strategies that specifically target those most

affected by drought economic indicators: output and employment in the agriculture sector and, particularly in the most vulnerable districts, mandals and communities.

- Moderating loss of employment during droughts remains a key challenge. The agricultural sector is the major employment generator for the state, with the total employment loss of more than 44 lakhs for 2002–3 linked to the estimated decrease in the agricultural output caused by drought. The analysis identified several opportunities outside the agriculture sector that can mitigate the impacts of drought on employment and income in the short to medium term, including (a) trade and transport (except railways), (b) the construction sector and related (cement, bricks, and steel) industry, (c) the mining and quarrying sectors, and (d) the poultry sector.
- Responses to drought depend on the situation of a particular household and may range from a change in farming decisions to migration to extreme cases of starvation, loss of health, and even life itself (including cases of suicide). These responses reinforce the findings of the analysis that tailored assistance is required for those in need.

## Areas for Future Action

The analysis revealed stark contrasts through which drought manifests itself at different geographic levels, on different economic indicators, on different crops and sectors, on different population groups, and on different measures of human well-being. The growing gap between the encouraging macroeconomic trends and the impacts on farmers and communities in drought-prone areas is particularly disconcerting. Thus, an effective strategy needs to combine statewide economic and sectoral policies with intensified, well-targeted efforts at the micro level:

- *Continue and accelerate the ongoing changes in the economic structure at the macro level.* This can significantly contribute to increasing the resilience of the state economy and/or its people to drought in the long term. These include facilitating growth of the tertiary sector; supporting the development of the livestock sector, particularly poultry; and encouraging a shift in cropping pattern from rice to less water-intensive crops to decrease vulnerability to drought impact (including reviewing and addressing unfavorable incentives associated with current agricultural input subsidies and rice procurement prices).

- *Encourage investments in sectors with significant employment potential for the labor displaced from the agriculture sector*, such as certain services (trade and transport), construction, mining, and quarrying subsectors, to moderate the impact of drought on affected communities in the short to medium term.
- *Initiate development and implementation of drought adaptation plans for the most affected areas* to deliver better targeted, coordinated, and packaged assistance to those in need. These plans would include (a) measures that promote a gradual shift to more sustainable agricultural practices (for example, changing cropping pattern in favor of less water-intensive crops), (b) other economic activities that are less vulnerable to drought (for example, livestock, agro-industry), (c) water conservation and watershed management activities, and (d) short-term relief and safety net measures to help protect the nutritional health and education attainments of affected communities. This initiative should use a participatory approach and build on the existing successful experiences with the community-based watershed management in Andhra Pradesh, as well as integrate relevant schemes by different departments.
- *Consider special support programs for marginal farmers, landless and poorest.* A particular challenge, as always, is to effectively reach out to those poorest and most vulnerable. The reason is that affluent farmers and households are typically better able to use alternative opportunities, including temporarily changing farming practices or migrating to other sectors, whereas the poorer farmers and landless laborers are least resilient to shocks.
- *Create a supporting institutional and policy framework* with the involvement of all levels of the Government (local, district, and state) to provide extensive technical assistance and other support mechanisms to farmers and communities for drought adaptation planning and action. It would need to be supported by adequate institutional arrangements to deliver assistance to communities, strengthened policies and incentives for encouraging diversification of rural economy and water conservation, an aggressive awareness campaign, massive capacity building efforts for all key stakeholders, and innovative financial schemes that mitigate the risks and startup costs of transition to different crops, technologies, and economic activities.
- *Explore and introduce innovative microfinancing and insurance schemes* for farmers that promote a shift to more sustainable practices. The probabilistic drought risk model developed in this study opens new,

and until today virtually nonexistent, growth opportunities for commercial agricultural insurance and credit. Furthermore, the analysis highlights the importance of ensuring that risk-sharing arrangements to help farmers finance their losses do not perpetuate the current situation of heavy dependency of farmers on rainfall. Helping farmers in drought-prone areas to maintain a business-as-usual scenario for some time will make the insurance product unviable and the transition harder in the longer term. This consideration is relevant to both the Government crop insurance schemes and innovative insurance products by the private sector, such as rainfall or weather insurance, which were recently offered to farmers in Andhra Pradesh. Rather, new financing products should be able to provide an incentive to permanently switch to alternative, more sustainable agricultural and economic practices, such as less water-intensive crops (particularly high value cash crops), livestock, or some agro-processing activities. The study suggests that one particular promising area of innovation in future risk financing products is the development of contingent financing schemes that could facilitate the transitional “drought adaptation” process. Two possible innovative financing products are proposed by the study: (a) drought adaptation insurance, which could provide coverage against risks of transition from nonviable in the long term but familiar farming business to a viable (agricultural and non-agricultural) business, and (b) drought adaptation credit, which could provide initial capital to shift to a long-term viable business.

- *Develop a Decision Support Toolkit* to provide a good scientific basis for supporting drought management and adaptation planning at different levels. Among other tools, the innovative modeling framework that emerged from this study, and which expands previous work on catastrophe modeling to include drought, offers significant opportunities for strengthening drought risk analysis, as well as planning and financing models, that can be used in various states of India and other drought-prone countries.

## **CHAPTER 1**

# **Introduction**

Drought sets off a vicious cycle of socioeconomic impacts beginning with crop-yield failure, unemployment, erosion of assets, decrease in income, worsening of socioeconomic conditions, poor nutrition, and, subsequently, decreased risk absorptive capacity, and thus increasing vulnerability of the poor to another drought and other shocks.

The mitigation of the impacts of drought has been a key area of focus of the Government of India (GoI) since the 1950s, as evidenced through programs, such as the Desert Development Programme, Drought Prone Areas Programme, National Watershed Management Programme for Rain-Fed Areas, National Calamity Contingency Fund, and National Agricultural Crop Insurance Scheme. However, the human and social costs of droughts remain devastating. Following a major drought in the summer of 2002, the worst since 1987, a significant slowdown in India's economic growth occurred in the fiscal year 2002–3.

### **Drought in Andhra Pradesh**

Andhra Pradesh is the fifth largest state in India, with a population of 76 million,<sup>1</sup> of which more than 70 percent lives in rural areas. Agriculture has historically been of key importance to the economy of the state. Irrigated

by three major rivers, Krishna, Godavari, and Pennar, Andhra Pradesh ranks among the top five states in terms of cultivable land and is one of the top producers of rice and fruit. It also leads in the poultry sector.

Andhra Pradesh is also one of the three states in India with the largest drought-prone land area.<sup>2</sup> It falls under the semiarid region of peninsular India and is broadly divided into three regions: coastal Andhra (comprising 9 districts), Telangana (10 districts), and Rayalaseema (4 districts). During the major drought of 2002, 22 of the total 23 districts of Andhra Pradesh reportedly had less than 75 percent of the normal rainfall during the monsoon season.

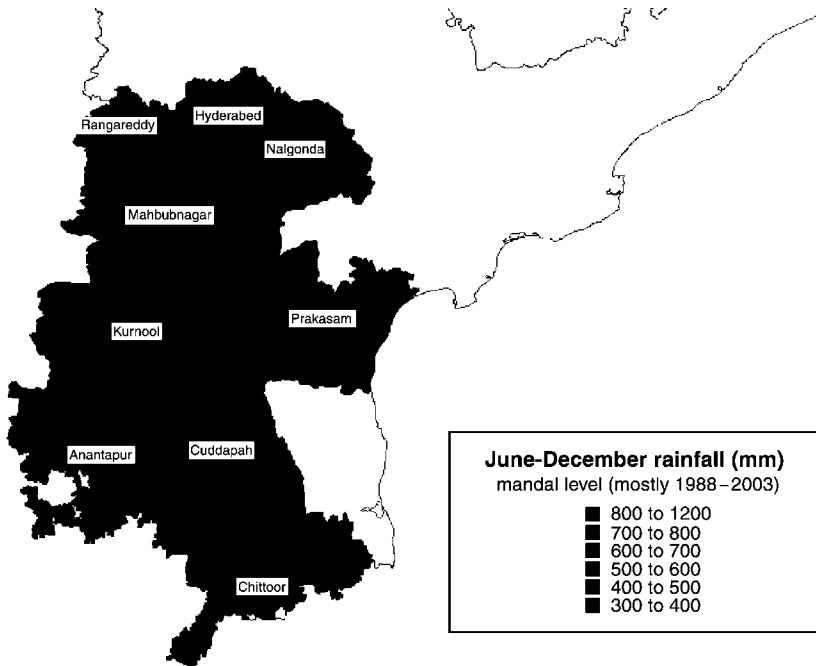
The strain on water resources has always been acute during low rainfall years in the state. This has further worsened in the past decades as the demand for water increased sharply owing to growth in agricultural production, population, and the industrial and urban sectors. The over-exploitation of groundwater for irrigation and the gradual decrease in the groundwater levels in certain pockets causing wells to dry up in the dry season is a further cause for worry. The impact is felt most by the farmers, agricultural laborers, and the rural community in dry-land rain-fed areas. Recently, increasing problems in water supply on a larger scale have affected urban centers, too.

Since the 1970s, the number of groundwater wells in Andhra Pradesh increased from 8 to 22 lakhs, and the area under groundwater irrigation increased from 10 lakh hectares (ha) to 26 lakh ha. This increased the overall level of groundwater use in the state from 16 to 43 percent. The use of groundwater varies across the state with some areas still having significant unused groundwater potential while in other areas groundwater use has exceeded 100 percent. Most of the groundwater is being used in areas not covered by surface irrigation. Groundwater use in these areas is 56 percent as against 16 percent in areas with surface irrigation, which covers only 5 percent of the state's geographical area.

The eight rain-shadow districts of the 23 districts in Andhra Pradesh, with an annual average rainfall well below the state average, are the worst affected by drought.<sup>3</sup> Four districts are situated in the Rayalaseema region (Anantapur, Chittoor, Cuddapah, and Kurnool), three in the Telangana region (Rangareddi, Mahbubnagar, and Nalgonda), and one in coastal Andhra region (Prakasam) (figure 1.1).

In the eight rain-shadow districts, surface water appears to be fully utilized with only a modest scope for further increase. In the medium term, irrigation projects can increase the area under surface irrigation by about 8 percent. Groundwater extraction is also quite high in these districts,



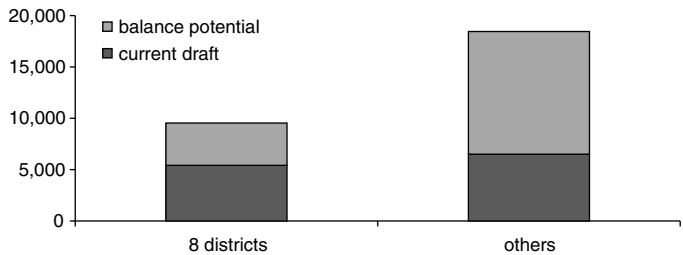
**Figure 1.1. Rainfall Levels in the Most Drought-Prone Districts in Andhra Pradesh**

Source: Ministry of Agriculture, Government of India.

compared to the state average amounting to about half of the total groundwater extracted in the state (figure 1.2). A large quantum of unutilized groundwater is estimated to be available in surface-water irrigated areas, and the Government of Andhra Pradesh (GoAP) plans to increase areas under the surface irrigation. However, there are serious technical and economic constraints to increasing the volume of irrigation water for these districts or at least for those areas within these districts that have become drought-prone hot spots. There is a wide recognition in the state of the need to start an adaptation process for a gradual shift to less water-intensive agricultural and other economic practices (such as livestock and agro-industry) that are more sustainable in water-deficit areas.

These eight districts are home to 35 percent<sup>4</sup> of the population of Andhra Pradesh (that is, about 30 million people). A large proportion is involved in agriculture (the economic sector most vulnerable to rainfall variability occurring in these districts) compared to the other 15 districts (31 percent versus 27 percent). The eight districts account for 43 percent of the cultivators and 36 percent of the agricultural laborers of the

**Figure 1.2. Groundwater Assessment for Irrigation in Andhra Pradesh  
(Million Cubic Meters)**



Source: Prasad 2002.

entire Andhra Pradesh population. While variations in income are significant, the average per capita income for these eight districts is below the state average (90 percent), and particularly low in Mahbubnagar (75 percent).

### **Andhra Pradesh's Drought-Related Initiatives**

A large number of drought-related initiatives are currently in place in Andhra Pradesh with support from the GoI, GoAP, and several donors (table 1.1 and annex 1). Examples of major programs include irrigation schemes by the Irrigation Department, the Calamity Relief Fund by the Revenue Department (Revenue [Relief] Department 1981 and 1995) and the Rural Guaranteed Employment Scheme by the Rural Development Department. Other important initiatives include a program to provide alternative crop seeds by the Department of Agriculture and groundwater monitoring undertaken by the Groundwater Department (Groundwater Department 2003). In 2004, the GoAP created a new Department for Rain-Shadow Areas Development to support the economic and social development in the most drought-affected communities. The vast majority of these areas are in the eight districts covered by the study.

There is considerable experience in drought management at the community level through watersheds programs, sponsored by GoI and/or GoAP, such as the Drought Prone Area Programme, Hariyali Watershed Development Programme, Indira Prabha, Neeru Meeru, and Joint Forest Management/Community Forestry Programme. In April 2002, the Water, Land and Tree Act, promoting water conservation and tree cover, was

**Table 1.1. Government Programs and Initiatives Addressing Drought in Andhra Pradesh: Illustrative List**

<i>Type of programs</i>	<i>Name of programs</i>
<b>Risk financing</b>	<ul style="list-style-type: none"> <li>• Calamity Relief Fund</li> <li>• National Calamity Contingency Fund</li> <li>• Crop insurance</li> </ul>
<b>Drought proofing</b>	<ul style="list-style-type: none"> <li>• Irrigation schemes</li> <li>• Drought Prone Areas Programme</li> <li>• Joint Forest Management/Community Forest Management</li> <li>• Water harvesting schemes</li> <li>• Microirrigation projects</li> <li>• Statewide irrigation development</li> <li>• Andhra Pradesh Rural Livelihood Project</li> <li>• Watershed Development Programme</li> <li>• Integrated Wastelands Development Programme</li> <li>• Rural Infrastructure Development Programme</li> <li>• Jawahar Gram Samridhi Yojna</li> <li>• Sampoorna Grameen Rozgar Yojana</li> </ul>
<b>Employment generation</b>	<ul style="list-style-type: none"> <li>• Self-employment programs on income generation</li> <li>• Employment Generation Mission</li> <li>• Women self-help groups</li> <li>• Food for work programme</li> <li>• National Rural Guaranteed Employment Scheme</li> </ul>

ratified by the Andhra Pradesh Legislative Assembly (*The Andhra Pradesh Gazette* Part IV-B 2002).

Drought-related issues have also been addressed, to varying degrees, by donor-funded rural development programs such as the U.K. Department for International Development-funded Rural Livelihood Program and the World Bank-funded Andhra Pradesh Rural District Poverty Initiatives Project and Andhra Pradesh Rural Poverty Reduction Project. The national Hydrology Project financed by the World Bank helped to organize and maintain the database relevant to water resource and drought management.

The Department of Planning with the technical help of the Central Research Institute for Dryland Agriculture has also developed, as part of preparing a drought management plan, a real-time decision support system to forecast and warn the farmers about the likely upcoming drought and suggest actions, such as changes in cropping patterns to mitigate these impacts. Research institutions, including the International Crop Research Institute for Semi-Arid Tropics and the Acharya NG Ranga

Agricultural University (ANGRAU), have been conducting extensive research on drought-resistant crops, appropriate agricultural strategies for drought-prone regions, and the socioeconomic impact of drought in select rural communities.

## **Objectives of the Study**

Since both the GoAP and GoI have numerous programs on drought and watershed management, this study was designed to complement these efforts by enhancing the long-term dimension of drought management planning through the assessment of economic implications of drought and the effectiveness of various policy measures to moderate its impacts at the state and drought-prone area levels. The scope and objectives of the study were agreed through extensive consultations with various concerned Government departments in Andhra Pradesh (Environment, Disaster Management, Agriculture, Rural Development, Rain-Shadow Areas Development, and Planning) and other stakeholders.

The objectives of this study were to:

- Develop a robust analytical framework for simulating the long-term impacts of drought at the micro (drought-prone areas) and macro (state) levels
- Conduct a quantitative assessment of the impacts under different scenarios
- Assist the GoAP in the development of a future-looking anticipatory strategy for adapting to drought risks and conditions of chronic water deficit

In addition to the macroeconomic and drought-management scenarios, the development of the modeling framework aims to account for the possible increase in frequency and severity of drought risks that may occur as the result of human-induced climate change.

The study developed and used a probabilistic risk assessment model that can simulate long-term agricultural and economic impacts of droughts under different climate change and risk mitigation scenarios. The specific steps involved in developing this model were:

- Analyzing historical data and developing an agro-meteorological model that can determine the impact of droughts on agricultural assets in Andhra Pradesh

- Developing a probabilistic drought risk model to assess the long-term direct impacts of droughts on losses in production outputs including risk metrics, such as probable maximum loss (PML) and average annual loss (AAL)
- Developing a macroeconomic model to capture indirect loss on various sectors of the economy, based on the direct loss given by the probabilistic drought risk model

The model is a powerful tool to undertake a thorough drought-risk assessment (with statistical outputs, such as AAL, conditional average loss by drought category, loss exceedance curve [LEC]) and to investigate the impact of alternative farming practices and climate change scenarios in each block of the eight districts.

The results presented in this report are aggregated to the (eight) district level and thus do not provide a full illustration of this model's capability to quantify the effect of drought and risk-coping strategies on crop yield and production at the block level. As a follow up to the study, the decision support tool can be applied in Andhra Pradesh to analyze the drought impacts and various adaptation options in detail, as per the specific needs of the responsible Government departments.

## **Broader Context of Adaptation to Climate Variability and Changes**

This study is linked to a larger program of research undertaken jointly by the World Bank and the GoI in a new strategic area of adaptation to climate variability and long-term changes. The importance of these issues is attributed to the magnitude of losses from climate variability, manifested by droughts, heat waves, floods, and cyclones, which has increased in India over the past decades. Furthermore, as global climate changes, the frequency and severity of these events are expected to increase.

The linkages between this study and a larger national study, entitled “Addressing Vulnerability to Climate Variability and Climate Change Through an Assessment of Adaptation Issues and Options,” are twofold. On the one hand, the modeling methodology, results, and recommendations that are derived from the Andhra Pradesh study inform and feed directly into the national adaptation study. On the other hand, the national study, which has a component in Andhra Pradesh, offers an opportunity to provide further technical assistance to Andhra Pradesh with respect to

reducing vulnerability of agriculture and rural communities to climate variability and drought.

## **Structure of the Report**

The report consists of six chapters, starting with this Introduction. Chapter 2 provides a historical overview of the impact of drought on the Andhra Pradesh economy. Chapter 3 describes the methodology for analyzing the long-term impacts of future droughts under different scenarios. Chapter 4 presents the results of the analysis of crop production losses caused by drought for the eight selected districts. Chapter 5 discusses the results of the analysis of direct and indirect economic losses at the state level. Chapter 6 contains the conclusions and recommendations. The report ends with eight technical annexes.

## **Notes**

1. Based on 2001 census of India.
2. The top three states with the most drought-prone land area are Rajasthan (21.9 million ha), Karnataka (15.2 million ha), and Andhra Pradesh (12.5 million ha). The Central Water Commission defines drought as a situation occurring when the annual rainfall is less than 75 percent of the normal (defined as 30 years average) in 20 percent of the years examined and less than 30 percent of the cultivated area is irrigated.
3. The definitions of droughts are discussed in annex 2.
4. Based on 2001 census of India.

## CHAPTER 2

# Drought and the Andhra Pradesh Economy: Historical Perspective

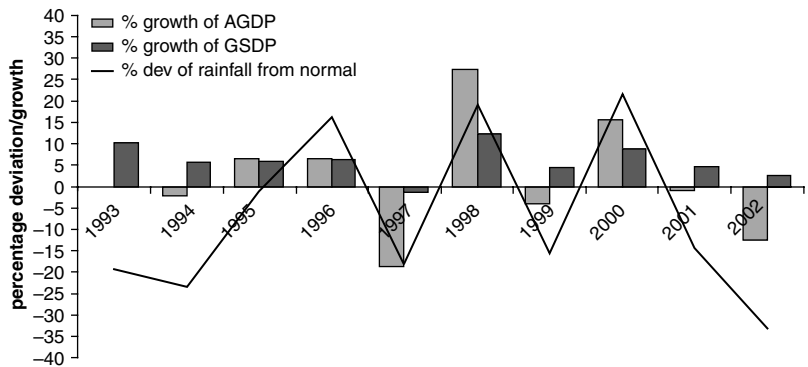
Drought undoubtedly causes loss of livelihood and human suffering at the individual and community level. Yet, its macroeconomic impact is less apparent.

Figure 2.1 demonstrates the relationship between rainfall and the performance of the Andhra Pradesh economy during 1993–2002. Rainfall is represented as percentage deviation from the normal and the economy by two indicators: (a) agriculture gross state domestic product (GSDP) and (b) overall GSDP. In particular, the graph shows that the growth of both agricultural gross domestic product and GSDP slowed down during the drought years of 1997, 1999, 2001, and 2002.

It is important to consider the impacts at a more disaggregated level. In the 2002 drought year there was a decrease in the contribution of agriculture to GSDP (figure 2.2). While agriculture contributed to about 21 percent of GSDP during the 2000–1 normal year, it decreased to about 15 percent in the following severe drought year. In particular, the contribution of water-intensive crops, such as rice, decreased from about 7 percent in 2000–1 to about 4 percent in 2002–3.

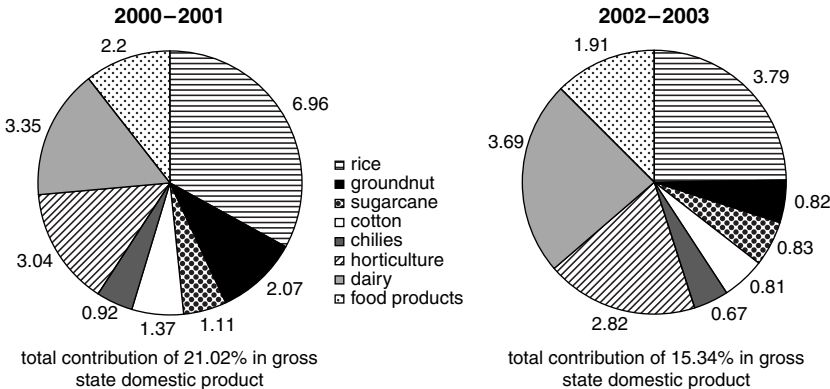
The economic impact of past droughts in Andhra Pradesh can also be captured through a comparative study of value of production (VOP)

**Figure 2.1. Rainfall and Economic Performance in Andhra Pradesh**



Note: AGDP, agricultural gross domestic product; GSDP, gross state domestic product.

**Figure 2.2. 2002 Drought Effect on Agriculture**



output tables. Sector-wise VOP tables were estimated for normal year 1998–9 and drought year 2002–3, at constant prices for 1998–9 (table 2.1). The effect of 2002–3 droughts is apparent in the changes in VOP of different sectors.

The agriculture sector was worst hit by the 2002 drought, and its VOP decreased by almost one-third. The production of rice decreased to such an extent that the state needed to import rice. Similarly, decrease in output of other food grains and food crops resulted in imports from other states.



**Table 2.1. Sector-Wise VOP, Constant 1998–9 Prices** (Rs. Lakhs)

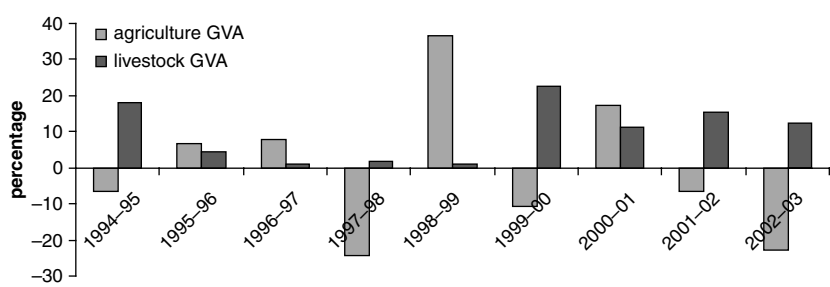
<i>Sectors</i>	<i>VOP 1998–9</i>	<i>VOP 2002–3</i>	<i>Percent change</i>
Primary sector	4,883,329	5,244,715	7
Agriculture	3,073,906	2,251,601	– 27
Rice	1,203,027	741,465	– 38
Jowar (sorghum)	35,957	41,443	15
Maize	68,442	73,502	7
Other food grains	159,296	173,853	9
Groundnut	298,189	128,745	– 57
Other crops	1,308,995	1,092,593	– 17
Livestock	948,749	1,677,690	77
Forestry and logging	167,625	170,715	2
Fishing	351,600	583,779	66
Mining and quarrying	341,449	560,930	64
Secondary sector	8,077,322	9,949,970	23
Construction	1,022,581	1,524,684	49
Tertiary sector	7,426,711	9,844,996	33

Contrary to the economic impact on agriculture, the livestock sector experienced an increase of 77 percentage points in production despite the drought. While this could be due to some Government interventions in the poultry sector, which performed especially well, it highlights a potential for greater resilience to drought in this sector. Figure 2.3 compares the annual changes with respect to the previous year in gross valued added (GVA) of the agricultural sector and the livestock sector during 1994–2003. The GVA is calculated as the difference between the value of output and the value of inputs excluding consumption of fixed capital. Drought years 1997–8 and 2002–3 clearly affected the agriculture sector, with a loss in GVA of higher than 20 percentage points, while these drought events did not significantly affect the livestock sector.

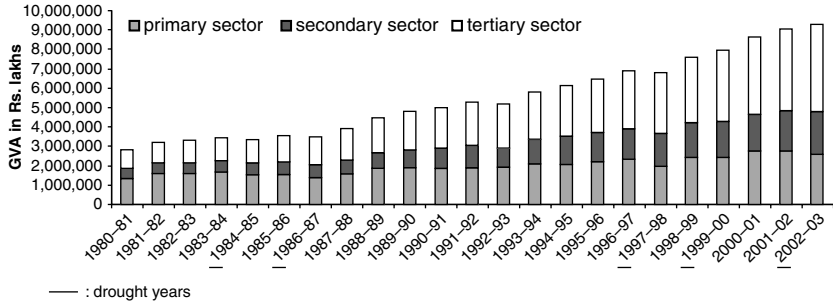
These data indicate that a structural change in the primary sector activities, such as diversifying into livestock production, is likely to make the economy (as well as the primary sector itself) less vulnerable to drought. Indeed, during the drought of 2002, the primary sector as a whole experienced an increase in VOP of 7 percent despite a decrease in agricultural sector VOP.

The structure of the Andhra Pradesh economy and the impact of drought are shown in terms of changes in the GVA in various sectors of the economy and interrelations between them over the period 1980–2003 (figure 2.4). The key drought years are marked for quick identification. Each of these years can be compared with the preceding normal/drought

**Figure 2.3. Percentage Changes in Agriculture and LGVA, 1993–94 Constant Prices**



**Figure 2.4. Sector-Wise GVA Time Series, 1980–2003, 1993–94 Constant Prices**



year to assess the impacts on the overall economy and across the three aggregate sectors (primary, secondary, and tertiary). Importantly, while the agriculture GVA was lower for every drought year as compared to the previous year, the two latest drought periods (1999–2000 and 2002–3) did not cause an absolute reduction in the overall state GVA.

An apparently increasing resilience of the overall state economy to drought, as observed from figure 2.4, is because the share of agriculture has gradually decreased while that of the secondary sector and, particularly, that of the tertiary sector, has increased significantly. This trend suggests that the impact of drought on the overall economy of the state is decreasing over

time, as the impact on agriculture is kept under check by other sectors of the economy.

To summarize, droughts continue to have a negative impact on the economy of Andhra Pradesh, particularly on the performance of the agriculture sector and on the lives of the millions of rural poor. However, the impact of drought on the overall economic indicators has lately been decreasing owing to structural changes, such as the growth of the secondary and tertiary sectors. Furthermore, the impact of drought on the rural economy is showing, on average, some signs of moderation due to the increasing role of the less vulnerable livestock sector.



## **CHAPTER 3**

# **Methodological Framework**

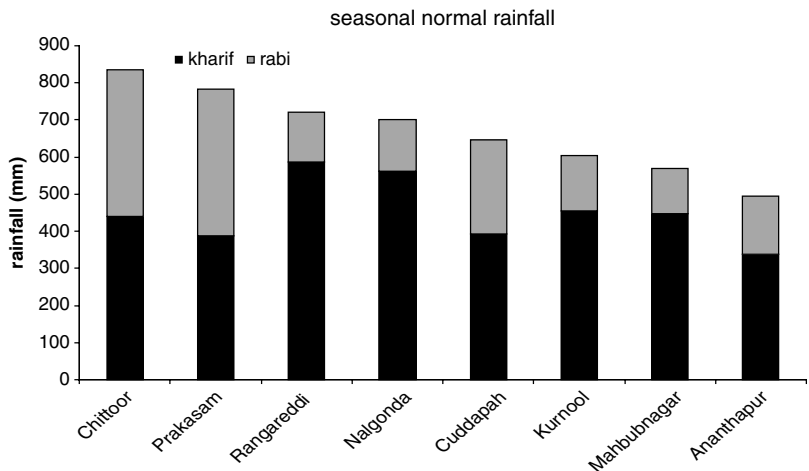
The methodological framework developed for this study intended to (a) conduct a detailed risk analysis of impacts of drought events on yield and production at the block and district level and (b) assess the direct and indirect economic impacts at the state level.

### **Selection of Districts and Crops for Analysis**

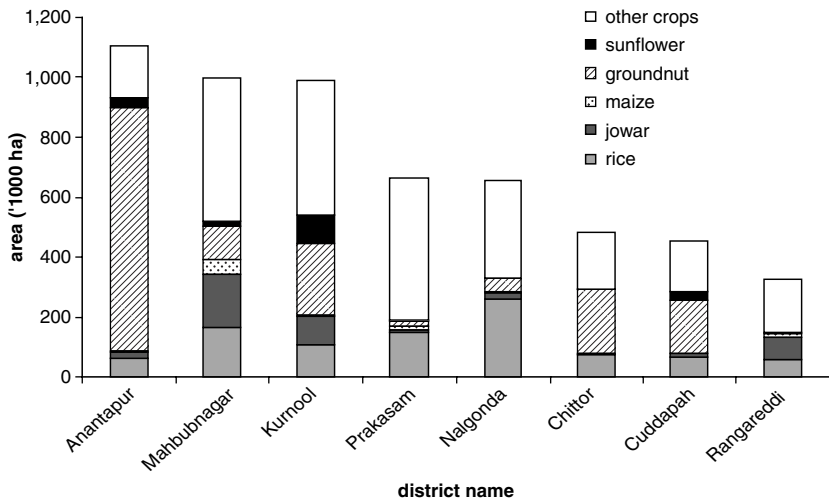
The major part of the modeling framework focuses on drought risk analysis in the eight most drought-prone districts: Anantapur, Chittoor, Cuddapah, and Kurnool in the Rayalaseema region; Rangareddi, Mahbubnagar, and Nalgonda in the Telengana region; and Prakasam in the coastal Andhra region. Rainfall in these districts is well below the Andhra Pradesh average of 938 millimeters (with the southwest monsoon in June–September months contributing 66 percent and northeast monsoon in October–December months contributing 24 percent), and is particularly low in Anantapur and Mahbubnagar (figure 3.1).

Four dryland crops (jowar [sorghum], maize, groundnut, and sunflower) and one water-intensive crop (rice) are mainly affected owing to drought in these eight districts. These crops together account for the largest land area used for agriculture in most of the eight districts (figure 3.2) and

**Figure 3.1. Seasonal Rainfall Deviation in Eight Selected Districts of Andhra Pradesh**



**Figure 3.2. Crop Area in the Eight Selected Districts of Andhra Pradesh**



account for more than 80 percent of the all-crop production variability in these districts.

The analysis of drought events in the eight districts can be extended to assess the economic impact of these events at the state level. The eight districts contributed to about 70 percent of the decrease in agricultural production at the state level during the past eight drought events (1980–1,

1984–5, 1985–6, 1986–7, 1992–3, 1994–5, 1999–2000, 2002–3). The eight districts account for 88 percent of the total variability in crop losses at the state level.

### **Probabilistic Drought Risk Assessment Model**

A probabilistic drought risk assessment model was developed to estimate the economic impact of droughts and to assess the effects of different drought mitigation strategies and climate change scenarios. Such models are well established to deal with rapid onset disasters (for example, earthquakes, cyclones, and floods).<sup>1</sup> The economic impact of drought is more complex than that of rapid onset disasters because the impact of rainfall shortage on agricultural assets (for example, crops) is a complex hydrologic and agronomic phenomenon, and drought normally lacks the highly visible direct impacts associated with rapid onset disasters, making indirect economic losses difficult to quantify. Because slow onset disasters, such as drought, have different characteristics and are more difficult to quantify than rapid onset events, it required an innovative risk assessment model using a different risk management paradigm than the one applied for rapid onset disasters. To the best of our knowledge, this is the first time ever that latest catastrophe modeling techniques have been used to address the impact of drought.

The drought risk assessment model comprises four main modules (figure 3.3): hazard, vulnerability, direct loss, and indirect loss.

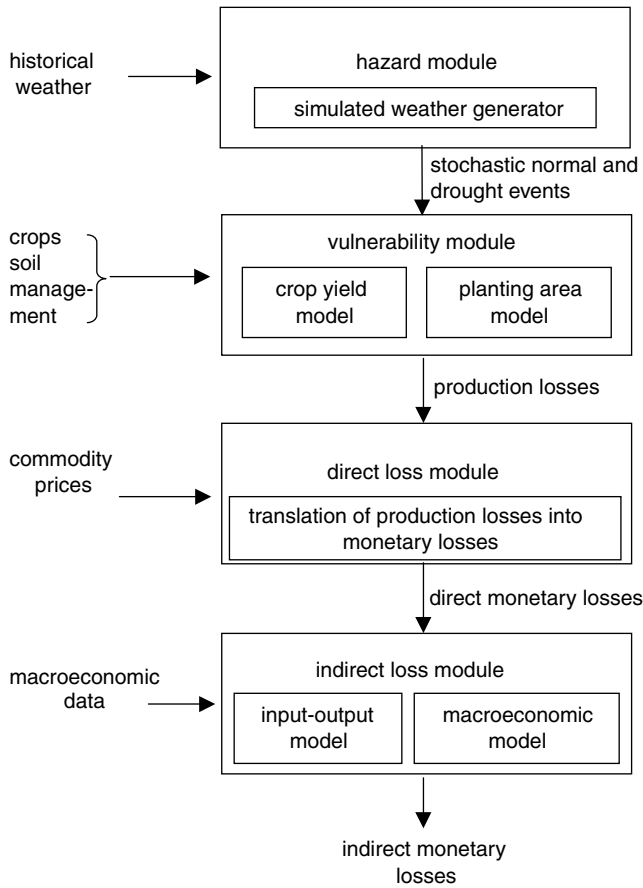
#### ***Hazard module***

In the hazard module, daily weather data (precipitations, air temperature, solar radiation, and wind speed) are simulated over a period of 500 years, based on historical data at a location. Normal and drought events (for example, minor, moderate, severe drought) are captured from this time series and their frequencies calculated. The model is capable of simulating different climate change scenarios.

The hazard module defines the frequency and severity of a drought event at a specific location. This is done by analyzing historical data on the severity and frequencies of drought in Andhra Pradesh.

The first step is to define precisely what a drought event is. Several definitions of drought have been proposed in the literature (see annex 2). The Standardized Precipitation Index (SPI) based on the precipitation deficit over a specified period of time was selected for this study (McKee et al. 1993; and annex 3). The SPI quantifies the impact of drought on the

**Figure 3.3. Probabilistic Drought Risk Assessment Model**



availability of different water resources. Soil moisture conditions respond to precipitation anomalies on a relative short time scale (days), while groundwater, stream flow, and reservoir storage reflect the long-term precipitation anomalies.

In this study, the intensity of drought events is defined with respect to SPI values as shown in table 3.1. Each drought event, therefore, has a duration defined by its beginning and end and intensity for each month during which it occurs. SPI was computed at both district and block levels. The seasonal rainfall at block level was aggregated to the district level to compute the district level index and to the eight districts study areas. This allowed simulation of crop yields at different stages of drought through the vulnerability module.



**Table 3.1. Drought Events and Standard Precipitation Index Values**

<i>SPI values</i>	<i>Event</i>
–0.5 to 0.5	Normal
–1.0 to –0.5	Minor drought
–2.0 to –1.0	Moderate drought
–3.0 to –2.0	Severe drought
Lower than –3.0	Extreme drought

The simulation in this study was based on 30-year data. The frequency of drought over periods much longer than the period of observation was calculated by using a stochastic weather generator (WXGEN), which is embedded in the agro-meteorological model (see annex 4). The WXGEN was first parameterized based on historical data for the study region: daily rainfall data at the block level and other meteorological data at the district level. Daily weather data were then simulated for 500 years to generate the long-term drought frequencies (see annex 3).

Table 3.2 shows the simulated frequency of droughts, by category as defined in table 3.1 in each of the eight drought-prone districts of Andhra Pradesh, as well as the entire study region. The results were validated by comparing the historical and estimated exceedance probability curves (EPC) that have shown a good match (see annex 3). Review of rainfall aggregations (from block to district to the region of eight districts) showed that the drought category (minor, moderate, and so on) at the block level does not necessarily translate to the same category at the district and regional level. Similarly, return period of a drought category for a block need not be the same for the district as well as the region.

**Table 3.2. Simulated Return Periods (in Years) of Droughts in Drought-Prone Districts**

<i>District</i>	<i>Minor</i>	<i>Moderate</i>	<i>Severe</i>	<i>Extreme</i>	<i>Any</i>
Anantapur	6.1	7.8	41.7	—	3.2
Prakasam	6.8	8.9	29.4	—	3.4
Rangareddy	7.5	7.7	35.7	500.0	3.4
Nalgonda	7.4	6.8	41.7	—	3.3
Chittoor	6.5	9.6	38.5	500.0	3.5
Cuddapah	6.3	9.1	35.7	250.0	3.3
Kurnool	6.8	7.9	38.5	500.0	3.3
Mahabubnagar	6.8	7.5	41.7	500.0	3.3
Eight districts	6.8	8.2	38.5	—	3.3

Source: Model simulations based on historical data.

Note: —, not available.

### ***Vulnerability module***

The vulnerability of the agricultural assets (for example, crops) at risk to simulated weather events is estimated from a crop yield model (annex 5) and a planting area model (annex 6). The crop yield model simulates crop yields for different drought events. Farmers' crop planting decisions are estimated through the planting area model. Production is the product of crop yield and cropped area, while production loss for a given drought event and crop is calculated as the difference between production during a normal year and production in a given drought year.

This module quantifies the damage caused to each asset by the intensity and duration of a given drought at a site. Drought mainly affects flow items, such as crops, while rapid onset disasters cause main losses among stock items. Asset classification for drought is based on a combination of crops and sensitivity to water.

In addition to the five selected crops, livestock was also considered, because drought directly affects the productivity of livestock by affecting the availability of drinking water, fodder, and so on. Area, yield, and production data were available from the Directorate of Economics and Statistics of Andhra Pradesh for the past 3 years at block level and for the past 10 years at the district level. However, these data are available only on an annual basis.

Livestock data were obtained from the four-yearly livestock census of Andhra Pradesh of 1993 and 1999 at district level. An analysis of the livestock census of Andhra Pradesh since 1951 did not show the affects of droughts conclusively (see table 3.3). The lack of annual livestock data precluded any direct quantitative assessment of the impact of drought on

**Table 3.3. Livestock in Andhra Pradesh**

<i>Census year</i>	<i>Total livestock (in thousands)</i>	<i>Percent change</i>
1951	34,287	—
1956	29,513	-14
1961	32,643	11
1966	31,594	-3
1972	33,064	5
1977	31,472	-5
1983	35,756	14
1987	33,667	-6
1993	32,911	-2
1999	36,010	9

Note: —, not available.

livestock. It was captured indirectly through the macro model developed in the economic module.

### ***Crop yield model***

In this study, damage was measured as the loss in yield of the selected crops. Loss in yield could be estimated from simple statistical relationships between yield and drought/nondrought categories. However, since the study aimed to analyze a wide range of response options and eventually the effects of climate change, statistical relationships would not suffice, as they cannot allow estimates of yield changes in circumstances not yet experienced. Thus, a simulation model of crop growth and, if possible, water availability and livestock production was sought.

A number of models were considered depending on whether they were well established, tested in practice, likely to be maintained over the next 5–10 years, and suitable for application in drought-prone agricultural systems such as those in Andhra Pradesh. These included the Decision Support System for Agro-Technology Transfer suite of models maintained by the International Consortium for Agricultural Systems Applications and the Environment Policy Integrated Climate (EPIC) model developed by scientists from the U.S. Department of Agriculture Agricultural Research Service, Soil Conservation Service, and Economic Research Service. The EPIC (Sharpley and Williams 1990; Izaurre et al. 2003) model was selected because it provided a more coherent modeling environment and there was relevant experience with its application in India (Priya and Shibasaki 1998a, b).

The EPIC model was originally designed to assess the effect of soil erosion on productivity; however, it helps answer a larger number of research questions. The model simulates the effects of management decisions on soil, water, nutrient, and pesticide movements and their combined impact on soil loss, water quality, and crop yields for areas with homogeneous soils and management. Some of the important components of EPIC are WXGEN; hydrology, erosion and sedimentation, and nutrient cycling; crop growth; tillage; economics; and plant environment control.

The five crops—rice, groundnut, sunflower, maize, and jowar (sorghum)—selected for the analysis had already been included in EPIC, but needed to be modified to reflect conditions in Andhra Pradesh. About 47 parameters relating to crop phenology, its environment, and crop growth in a stressed environment are used in EPIC. Some parameters that are used to estimate outputs (nutrient levels at various times in the growing season, and so on) were not used in this study. Parameter values for the selected

crops and the management practices associated with them were based on previous modeling exercises with EPIC and on advice from experts at ANGRAU, Hyderabad. Annex 5 presents detailed technical information on the EPIC model and its application in this study.

An important decision during model development was the level of hydrological modeling required. EPIC calculates soil moisture based on rainfall and irrigation data. Rainfall data were available at the block level. The availability of irrigation water depends on both local rainfall, which recharges surface dams and shallow wells, and water reaching a block through rivers, canals, and pipes. River flows and reservoir storages do not depend on local rainfall but on the catchments that were outside of the study area. An analysis of available data suggested that a detailed hydrological model was not feasible at either the block or larger scale. Irrigated and rain-fed areas were computed in the planting area model by crop, by season, and by block. EPIC was administered for two scenarios—irrigation and rain-fed—for each crop, for each block, and then superimposed on the respective areas to calculate production. This approach eliminated the need for a hydrological model.

### ***Planting area model***

Farmers take planting decisions at the beginning of the season based on economic parameters (for example, expected commodity price at harvest) and agro-meteorological parameters (for example, onset of monsoon, expected rainfall levels). Production flexibility is integral to the practice of dry-land farming (Jodha 1981). When crop failure is foreseen, farmers change their cropping patterns to focus their efforts on crops that have a greater chance in adverse weather conditions, as seen in semiarid tropics of India (Walker and Ryan 1990). Farmers' plans for the rainy season are contingent on rainfall, and thus the relative importance of rainy and post-rainy crops fluctuates seasonally. As a result, the area of Kharif season crops is variable.

This variability is not a source of risk but a proactive response to weather risk. An example of area variability (Walker and Ryan 1990) is the substitution of sorghum by castor that is induced by the late arrival of monsoon in Aurepalle. Late-planted jowar (sorghum) is susceptible to pests and so farmers prefer to plant castor. The response to agro-climatic events is even stronger in Mahbubnagar because of the short period of about two to four days after the onset of monsoon available for planting. Low soil moisture causes farmers to reduce cultivated area, increase intercropping, and increase use of short-duration and low water-requiring

crops (Gadgil et al. 1988). Therefore, production flexibility is a key feature of farmers' adjustments to weather variability.

A planting area model was built to capture the impact of rainfall variability on planting areas at district level. The development of a behavioral model representing the farmers' planting decision was beyond the scope of this study. Instead, the model was used to estimate through statistical analysis the irrigated and rain-fed cultivated area in a rainfall scenario. Annual data of gross cultivated areas and gross irrigated areas at district levels from 1988–9 to 2002–3 were available. Unfortunately, seasonal data were not available. Several models were tested, and the selected model estimated the percentage change of gross cultivated area and gross irrigated areas with respect to percentage change of the annual cumulative rainfall level (annex 6).

Crop production losses were then estimated under drought events. Estimated crop production is equal to estimated crop yield multiplied by estimated crop area, at the block level under a given drought event. Crop production losses are defined as the difference between crop production simulated during a normal year and crop production simulated in a drought year for each of the five crops at the block level. Losses are then aggregated to various levels of administration (district, state) as required.

### ***Direct loss module***

The direct loss module converts weight units to value units with respect to commodity prices. Direct monetary losses are calculated and then risk metrics (AAL, exceeding probability loss, PML, and so on) are estimated.

The direct impact of drought is monetary loss to farmers caused by decreased production. Production losses were converted to monetary losses taking current market price of each crop into consideration. The direct monetary losses were then aggregated to various levels of administration. At this stage of modeling, an event loss table (ELT) was created with columns for event number, severity, frequency, and loss.

Since large uncertainties are inherent in model estimates of event severity, frequency characteristics, and consequent losses caused by such events, the model is constructed using probabilistic formulations that can incorporate this uncertainty into the risk assessment. Risk metrics produced by the model using the ELT provide the policy maker with essential information necessary to manage their risks in the future (box 3.1). The stochastic crop production loss model is explained in annex 3.

**Box 3.1****Risk Metrics**

AAL: This is the expected loss per year when averaged over a very long period (for example, 100 years). It is the summation of products of event losses and event probabilities of occurrence for all stochastic events in the loss model. The events are an exhaustive list affecting the block/district under consideration generated by stochastic modeling.

LEC: This represents the probability that a loss of any specified (for example, monetary) amount would be exceeded in a given year. This is an important catastrophe risk metric since it estimates the amount of funds required to meet risk management objectives.

PML: This is a subset of the LEC that represents the loss amount for a given probability or return period per year. The policy maker may decide to manage for losses up to a certain return period (for example, 1 in 100 years). It is thus the 100-year loss.

***Indirect loss module***

This module aims at estimating the indirect economic losses from drought. It provides a consistent methodology that allows capturing of the complex nature of drought impacts, including direct and indirect drought losses.

One of the major challenges in assessing the economic impact of drought is that contrary to rapid onset disasters, droughts normally lack highly visible impacts and generate large indirect losses compared to direct losses. Their impacts are generally nonstructural and spread out over large areas. Because of this difference, the economic impact of droughts cannot be captured only through crop production losses.

In the indirect loss module, indirect monetary losses are estimated through a macroeconometric model and an input-output model. The macroeconometric model estimates the impact of crop production variability on the variability of the GVA of primary, secondary, and tertiary sectors of the economy. The input-output model gives a detailed picture of the linkages between the different sectors and subsectors of the economy (including Government expenditure), the flow of goods and services, as well as employment. In particular, this model can track the impact of a production loss caused by a drought on the other economic sectors and Government expenditure. The indirect loss module links direct monetary

loss estimates at the block level, as assessed in the direct loss module, with estimated indirect drought losses at the state level.

### ***Input-output model***

An intersectoral input-output table, the basis of the input-output model, was developed for Andhra Pradesh to measure the interactions between the economic sectors at the state level. While the Central Statistical Organization has been constructing such a table for the India-wide economy since 1973–4, it was constructed for the first time for the state of Andhra Pradesh in this study. The table included the following sectors: agriculture (food crops, nonfood crops), mining, food processing industries, fertilizers, metal and metal product industries including capital goods, other manufacturing products, electricity, gas and water supply, construction, trade, hotels and restaurants, transport, storage and communication, financial and other business services, as well as community, social, and other services. The input-output table was prepared for 1998–9 and then updated for 2002–03 using recent available data (annex 7).

Table 3.4 presents the employment coefficients and output multipliers calculated from the input-output table for 1998–9. The employment coefficients are high for the agricultural sector (5.4), implying that the agricultural sector is the major employment generator of the state. The output multiplier for rice showed that a 1-unit (lakh) increase in final demand of rice resulted in 1.45 (lakhs) increase in gross output in the economy. These output multipliers were the same for maize, but slightly lower for jowar (sorghum) (1.43) and groundnut (1.40).

The input-output table depicts the economy of a particular year and thus cannot capture the dynamic changes in the economy over time. Such dynamic changes can be captured only through a macroeconometric model, as described below.

### ***Macroeconometric model***

The dynamic structure of the Andhra Pradesh economy is described in terms of changes in the GVA in various sectors of the economy and interrelations between these sectors. The major sectors analyzed in this model are:

- Primary sector, of which two most relevant subsectors—agriculture and livestock—were examined separately for sensitivity to drought
- Secondary sector, including manufacturing (both registered and unregistered), electricity, gas and water supply, and construction

**Table 3.4. Employment Coefficients and Output Multipliers 1998–9**

<i>Sectors</i>	<i>Employment coefficients</i>	<i>Multipliers</i>	<i>Sectors</i>	<i>Employment coefficients</i>	<i>Multipliers</i>
Rice	5.40	1.45	Leather products	1.14	2.11
Jowar (sorghum)	5.40	1.43	Fertilizers	0.89	1.09
Maize	5.40	1.45	Pesticides	0.89	2.61
Other food grains	5.40	1.52	Chemicals	0.89	1.82
Groundnut	5.40	1.40	Nonmetallic mineral products	0.95	1.95
Other crops	5.40	1.22	Basic metals and alloys	0.05	2.54
Livestock	5.40	1.42	Metal products, electric and nonelectric machinery and equipment	0.06	2.67
Forestry and logging	1.44	1.17	Transport equipment and parts	0.59	2.10
Fishing	0.68	1.25	Miscellaneous		2.20
Mining and quarrying	0.47	1.41	Construction	0.86	1.69
Food products	1.01	2.23	Railway transport services	0.32	2.00
Textile products	3.15	2.08	Communication	0.41	1.27
Wood products	9.27	1.61	Ownership of dwellings, real estate, and business services	0.02	1.12
Paper products	0.37	2.17	Public administration	0.92	—
Leather products	1.14	2.11	Ownership of dwellings, real estate, and business services	0.02	1.12
Rubber, plastic, coal, tar	0.45	2.12	Education, medical, and other services	1.09	1.79
Fertilizers	0.89	1.09	Public administration	0.92	—

Note: —, not available.



- Tertiary sector, including trade, hotels and restaurants, railways, transport by other means and storage, communication, real estate and business, banking and insurance, public administration, and other services

The macroeconometric model was used to investigate how the direct economic impact of drought in the eight selected drought-prone districts (captured through the previous modules of the drought risk assessment model) generates indirect economic impacts in these four sectors at state level. Specification of a macroeconometric model required postulating structural equations, which describe changes in the GVA in terms of certain variables and changes that directly influence the GVA.

The GVA was calculated as the difference between the values of output and inputs (at current or constant prices). However, the inputs did not include the consumption of fixed capital.<sup>2</sup> For example, for agricultural GVA the inputs are seed, chemical fertilizers, organic manure, current repairs and maintenance of fixed assets, market charges, irrigation charges, electricity, pesticides and insecticides, and diesel. Therefore, the specification of structural equations for GVA, in each of the sectors, included consumption of fixed capital as one of the explanatory variables.

Several specifications of the model in terms of sector-wise GVA were tested (annex 8), and the model best fitting the observed data during 1980–2003 is given below<sup>3</sup>:

$$\ln(\text{AGVA}) = 1.03 \ln(\text{ACFC}) + 0.25 \ln(\text{VOP}_{4,8}); \bar{R}^2 = 0.73$$

(10.53)                      (2.98)

$$\ln(\text{LGVA}) = 0.98 \ln(\text{LCFC}) + 0.24 \ln(\text{AGVA}); \bar{R}^2 = 0.90$$

(14.64)                      (5.32)

$$\ln(\text{SGVA}) = 0.72 \ln(\text{SCFC}) + 0.37 \ln(\text{AGVA}_1); \bar{R}^2 = 0.84$$

(8.77)                      (4.94)

$$\ln(\text{TGVA}) = 1.33 \ln(\text{TCFC}) - 0.12 \ln(\text{AGVA}_1); \bar{R}^2 = 0.98$$

(26.05)                      (-2.70)

[From the  $t$ -distribution on 8 d.f.  $P(|t| > 1.86) = .05$ ]

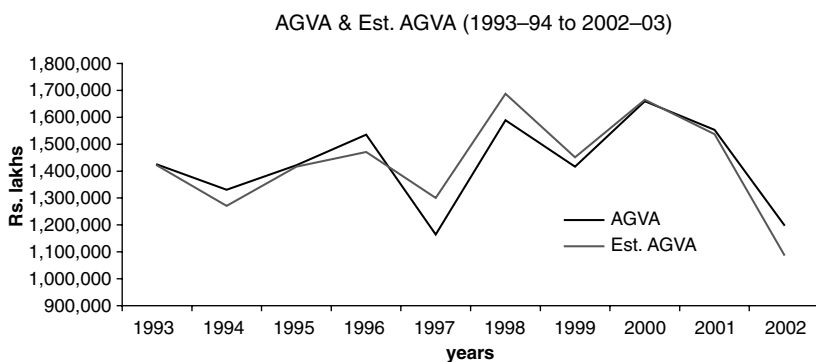
where  $\ln$  is the natural logarithm,  $\text{VOP}_{4,8}$  is the value of output of the four crops (rice, maize, jowar [sorghum], and groundnut) in the eight selected districts; AGVA is the agriculture GVA, LGVA is the livestock

GVA, SGVA is the secondary sector GVA, TGVA is the tertiary sector GVA, and  $AGVA_{-1}$  is last year's agricultural GVA; agricultural consumption of fixed capital (ACFC), livestock consumption of fixed capital (LCFC), secondary sector consumption of fixed capital (SCFC), and tertiary sector consumption of fixed capital (TCFC) are the consumption of fixed capital in agriculture, livestock, secondary sector, and tertiary sector, respectively. Numbers in parenthesis are the  $p$ -values and  $R^2$  is the coefficient of determination adjusted for the degrees of freedom.

The coefficients were calculated by the seemingly unrelated regressions (SUR) method and could be interpreted as partial elasticity coefficients. According to the macroeconometric model, a 1 percentage point change in the production of the four selected crops in the eight selected districts will generate a 0.25 percentage point change in AGVA. Likewise, a 1 percent change in the agricultural GVA would cause a 0.24 percentage point change in the livestock GVA. A 1 percentage point change in agricultural would cause a 0.37 percentage point change in the secondary sector GVA and  $-0.12$  percentage point change in the tertiary sector GVA in the next year. This macroeconometric model can explain between 73 and 98 percent of the variability of the dependent variables. The first equation estimating AGVA captured the peaks and drops observed during 1993–2002 (figure 3.4).

Because of the statistical limitations of a restricted sample size, the model described above should be considered preliminary. Some alternative macroeconometric models tested under this study showed a positive but statistically not significant elasticity coefficient of AGVA on SGVA,

**Figure 3.4. Estimated and Observed AGVA**



and a negative but statistically not significant coefficient of AGVA on TGVA (annex 8). Therefore, the impact of a change in the agricultural GVA on the GVA of the secondary and tertiary sectors should be analyzed with caution. In future applications, the model specifications could be further refined based on a larger data series.

## Notes

1. Gurenko and Lester (2003) developed a risk management approach for the financing of rapid onset disasters (earthquakes, cyclones, and floods) in four states of India (Andhra Pradesh, Gujarat, Maharashtra, and Orissa).
2. The net value added is defined as the difference between the GVA and consumption of fixed capital.
3. Other macroeconometric models tested included regression of detrended data using first differences and regression of detrended data using ad hoc linear trend over the period 1980–1 to 2002–3 (with a break dummy in 1993).



## CHAPTER 4

# Reducing Vulnerability of Agriculture to Drought in Eight Drought-Prone Districts

The results of the stochastic drought risk assessment model for the eight districts, as well as the impacts of alternative drought management and climate change scenarios, will be discussed. The latter are presented for the two most severely affected districts: Anantapur and Mahbubnagar. These results are selected illustrations of the capability of this model to investigate the impact of a variety of risk-coping strategies and climate change scenarios at the farm level.

### **Crop Yield Variability: Benchmark Case**

In Andhra Pradesh, 68 percent of rainfall is received during the southwest monsoon season from June to September, which is the main cropping season in the rain-fed areas. Maize, jowar (sorghum), groundnut, and sunflower are the major crops grown under rain-fed conditions during this season in the drought-prone districts. However, rice is becoming more commonly cultivated in rain-fed areas using irrigation water from wells, bore-wells, and tanks. The yields of the five major crops (rice, maize, jowar,

groundnut, and sunflower) were simulated by the probabilistic drought risk assessment model for each block of the eight districts and then aggregated to the district level.

### ***Variation in yields at block level***

The yields under normal conditions showed considerable variation across blocks and districts for the same crops. Thus, different locations appear to favor different crops (figure 4.1). For example, groundnut does better in a small region in the northwest, while jowar does better in the southwest and sunflower in the northeast. Maize does not show significant areas of high yield.

Figure 4.2 shows the increasing impact of droughts on yields. During severe droughts, losses of yields were almost uniform across most districts and blocks. However, rice is particularly affected in Anantapur and Kurnool, and sunflower shows greater sensitivity in the southwest while maize shows less sensitivity than other crops.

### ***Variation in yields at district level***

Table 4.1 shows the average yields in normal years and yield losses in drought years for rice in each of the eight districts. Similar to block-level results, these losses vary significantly among the districts, especially for rain-fed crops. Importantly, different crops can be particularly vulnerable in different districts, implying that district (and block)-specific coping strategies are needed.

It must be stressed that the model simulates yield and production (yield  $\times$  planted area) at the block level using a relatively simple and coarse model of shifts in planting areas at a block scale (that is, the model only crudely adjusts the allocation of irrigation water among crops depending on the level of rainfall). In reality, however, farmers routinely make adjustments in farming practices, including the allocation of irrigation water among crops depending on immediate water needs.

For example, the model assumes that, once the planting areas have been selected, irrigation water is given to rice on a priority basis irrespective of rainfall and thus estimates that maize yield is more affected by drought than rice. However, during the drought of 2002, the output of crops, such as jowar, maize, and other food grains, showed an increase against the drastic fall in output of rice. This clearly indicates that, in the situation of acute water deficit caused by a major drought, farmers “rationalized” the use of available water by favoring less water-intensive

**Figure 4.1. Average Normal Yield by Crop (Metric Tons per Hectare)**

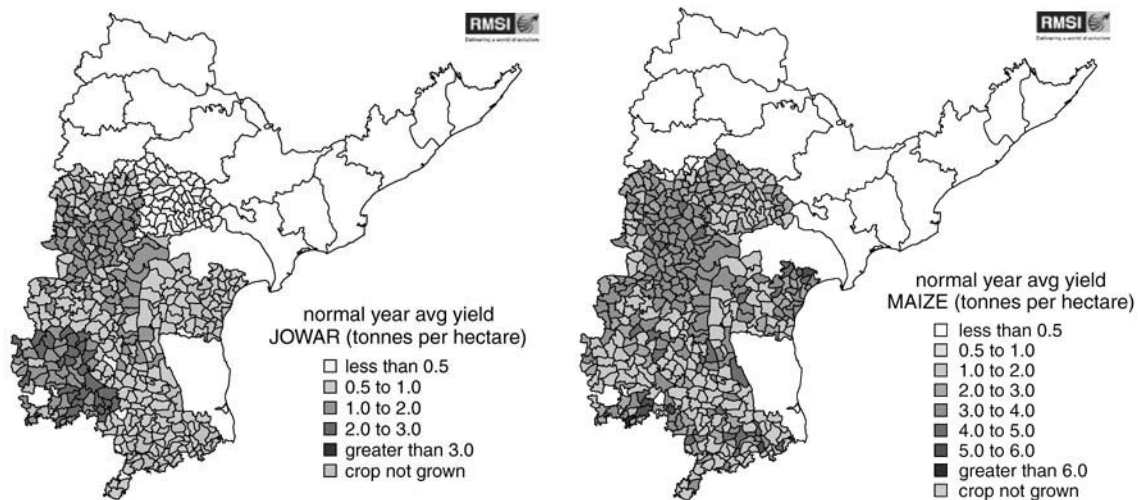
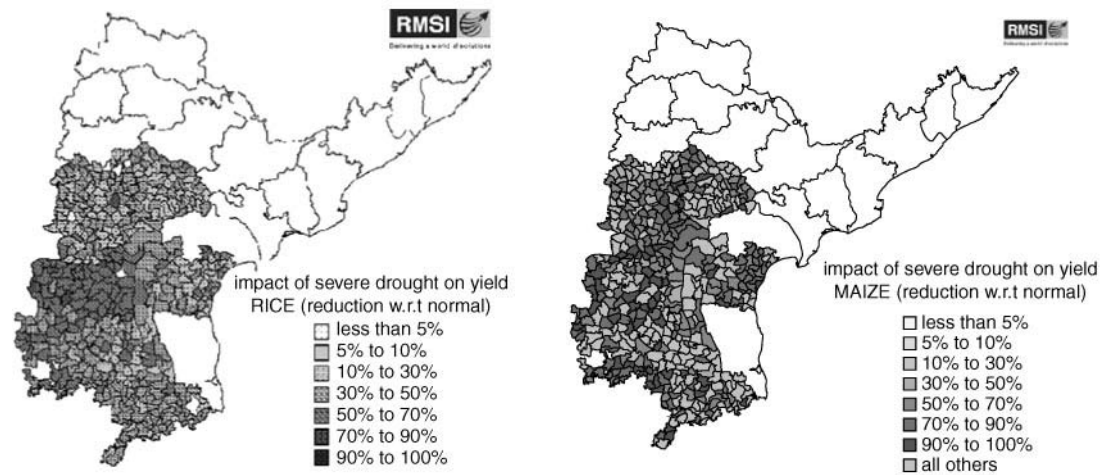


Figure 4.2. Impact of Severe Drought on Yield (Percent Decrease With Respect to Normal Yield)





**Table 4.1. Rice Yields in Normal Years and Rice Yield Losses in Drought Years**

	<i>Ananthapur</i>	<i>Mahbubnagar</i>	<i>Kurnool</i>	<i>Cuddapah</i>	<i>Chittoor</i>	<i>Prakasam</i>	<i>Rangareddy</i>	<i>Nalgonda</i>
Normal (MT/ha)	2.87	2.15	2.59	2.73	2.86	3.10	2.37	2.69
Yield losses in drought years (percent normal yields)								
Minor	14	10	13	11	10	10	19	8
Moderate	27	19	32	21	18	19	24	16
Severe	45	26	62	31	35	33	31	29

crops. Thus, farmers, using traditional knowledge, common sense, and guidance from local experts and extension officers, do adapt to rainfall variability.

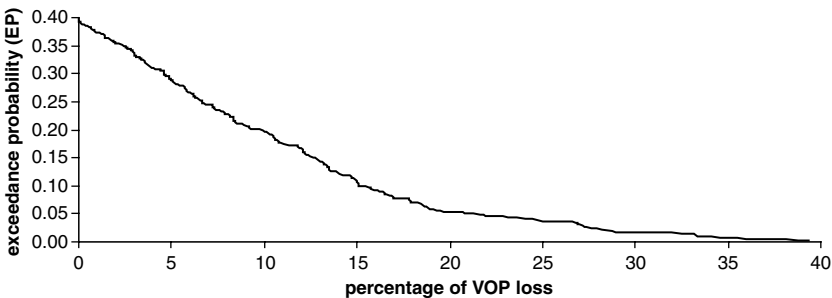
The key question is how effective their coping strategies are and whether these can be improved upon. While the model in its current form was quite successfully validated in terms of yields and production for the eight districts based on historical data, integrating more advanced farming behavior modeling techniques is a critical area for further developing and applying this analytical tool. The modeling capability to simulate the behavior of single farmers could be used to assess farm level decisions and help select those that are economically viable.

### Crop Production Losses

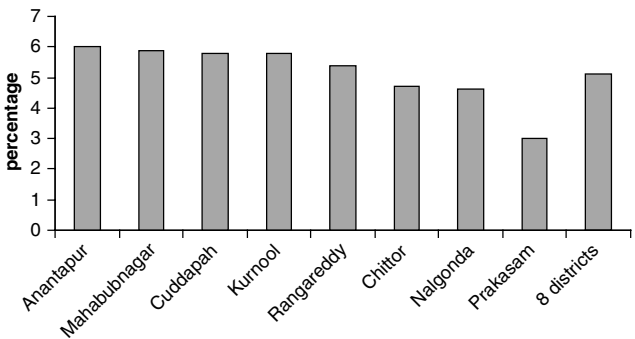
The EPC of the estimated loss of VOP for the region of the eight drought-prone districts is defined as the difference between the VOP of the five crops during a normal year and the VOP during a drought year. The VOP was less than that in a normal year 40 percent of the time; that is, the eight districts faced a loss in VOP because of drought every two to three years (2.5 years on average). The VOP loss is as high as over 15 percent once every 10 years on average and exceeds 25 percent once every 25 years (figure 4.3).

The AAL of output owing to exposure to drought (averaged over a long series of years) was 5 percent for the eight districts in this study, assuming no changes in the current cropping pattern. This is a significant value for average loss. The AAL of output increased to 6 percent in the worst-affected Anantapur, closely followed by Mahabubnagar, and decreased to 3 percent in Prakasam district (figure 4.4.). As shown above, there were further variations within districts and across blocks. Even greater disparities in impacts of and resilience to drought can be

**Figure 4.3. Crop Production Losses Caused by Drought in the Eight Districts: EPC**



**Figure 4.4. Average Annual Loss of Value of Production Output, by District**



expected at the farm and household levels. Averages always mean that individual farmers will experience greater losses than a district or block average if their particular crops are badly affected. For small and marginal farmers, even a 10 percent or 5 percent decrease in output could mean falling below the poverty line.

A survey of communities in one of the poorest and worst-affected districts, Mahbubnagar, showed that depending on the situation of a particular household, responses ranged from a change in farming decisions to migration to extreme cases of starvation, loss of opportunities and health, and even life itself (box 4.1). These responses further highlight the findings of the analysis that the impacts of drought are highly localized and differentiated and require targeted assistance to those in need.

**Box 4.1****Coping With Drought: Findings From Mahbubnagar**

A survey of drought-affected communities conducted in five blocks of the Mahbubnagar district provided insights into how farmers and villagers change their behavior during a drought season:

*Irrigation practices*

- Increasing the number of tube-wells and decreasing the number of traditional tanks and open-wells
- Increasing the depth of the tube-wells to between 200 and 300 feet (approximately 61–91 meters) to access lower groundwater levels

*Cropping practices*

- Decreasing the cultivable area because of lack of water and labor because family members moved out of the district
- Temporarily adapting crop cycles to suit the time of rainfall
- Limited examples of changing to high yield crops, horticultural (sweet orange, mango, acid lime, and so on), and mixed cropping promoted by Government programs

*Migration/labor*

- Migration of members or whole families to outside the districts for livelihood, such as construction labor
- Sending children to work as laborers
- Working at lower wages to generate some income

*Financial*

- Taking loans from money lenders (50–60 percent of total loans) or self-help groups, where debts of farmers vary from Rs. 30,000 to Rs. 200,000 (70 percent for agricultural inputs and 30 percent for marriages, health, house construction, or renovation)
- Pawning of household items and jewelry
- The poorest people reduce expenditure on basic needs, leading to malnutrition and, in extreme cases, starvation
- Sale of livestock at depressed prices owing to lack of fodder or agricultural work for the livestock

*Extreme practices*

- Suicide

Source: Winrock International, India (2005).

## **Adaptation Strategies at the Farm Level**

Farmers adapt, to some extent, their irrigation and cropping practices in response to the changing level and pattern of rainfall. However, these changes are usually short term and aimed at surviving the extreme drought rather than preparing for subsequent droughts, or to the chronic conditions of increased water deficit, occurring in some parts of the study districts. The falling groundwater table (200–250 m) is an indication that current practices are unsustainable in the long term. Energy consumption for pumping has become a costly input for rice irrigation, and, since power supply to agriculture is heavily subsidized, it drains state finances and contributes to power shortages.

There is a need for a more sustained shift to water conserving practices. Given the decreased groundwater resource and increased energy costs, the GoAP is taking measures to ensure that water is used more efficiently and that the demand for irrigation water is reduced. It has already taken an initiative to curb the drilling of bore-wells by bringing the Andhra Pradesh Water Land and Trees Act (*The Andhra Pradesh Gazette Part IV-B 2002*) into effect. Its new energy policy discourages rice cultivation by not providing free power to farmers for the second rice harvest.

Rice requires 1,200 millimeters of water during its growth period with any shortfall from rainfall being made up from irrigation. In the simulations in this study, 600 millimeters of irrigation were provided at regular intervals over the 120-day growing season for rice. By comparison, rain-fed crops (maize, jowar, groundnut, and sunflower) require only 400–600 millimeters of water to complete their life cycle. Yield of rain-fed crops decreases if the crops suffer moisture stress during critical stages of their life cycle and particularly during early growth or at the time of grain setting, which might well happen during a drought year. Irrigating the crops at critical stages during their life cycle in water-scarce periods can increase their yield. Providing 50 millimeters depth of water at one or two critical stages and adding fertilizer along with the irrigation water can further enhance yield.

### ***Reallocation of irrigation water by reducing cultivable rice area***

Two main scenarios were investigated, under which the area planted with rice is decreased so that the water saved can be redistributed to other crops, as follows:

- Case 1: single irrigation of rain-fed crops at the flowering stage or its equivalent.
- Case 2: first irrigation as above plus second irrigation at the time of yield (grain formation) (see also box 4.2)

#### **Box 4.2**

#### **Reducing Cultivable Rice Area: Assumptions**

According to local experts, one life-saving irrigation of 50 millimeters depth of water can be given to 24 ha if one hectare of rice cultivation is reduced, as rice requires 1,200 millimeters of water during its growth period. This recommendation, which holds for all rain-fed crops (groundnut, jowar [sorghum], maize, and sunflower), is based on the assumption that there is no significant rain during severe drought conditions and the entire 1,200 millimeters of water required for rice is provided by irrigation.

Two cases were investigated under this risk-coping strategy:

*Case 1:* One life-saving irrigation of 50 millimeters depth of water is given for 24 ha of rain-fed area for every hectare of rice cultivation reduced. Irrigated area for rice that needs to be reduced is calculated from the total rain-fed area of the four crops in the ratio of 1:24. The balance of irrigated rice area is left as is.

*Case 2:* Two life-saving irrigations, each of 50 millimeters depth of water, are given for 12 ha of rain-fed area for every hectare of rice cultivation reduced. Irrigated area for rice that needs to be reduced is calculated from the total rain-fed area of the four crops in the ratio of 1:12. The balance of irrigated rice area is left as is.

Cultivated areas were reallocated using a simple rule. The cultivated rice area was reduced to provide irrigation to the full area of each of the other crops with one or two irrigations according to the requirement. If there was insufficient cultivable rice area to yield the necessary savings in irrigation water, the area of the other crops irrigated was reduced accordingly. This strategy of changing the cultivable area could be made more realistic by considering the yield value of different crop combinations and farmer preferences toward risks.

The study showed that under the single irrigation scenario cultivable rice area should be reduced by 54 percentage points in Anantapur and by 8 percentage points in Mahbubnagar. This difference is because cultivable rice area in Anantapur is less than half that in Mahbubnagar, while the reverse applies to the area under the four rain-fed crops (figure 3.3).

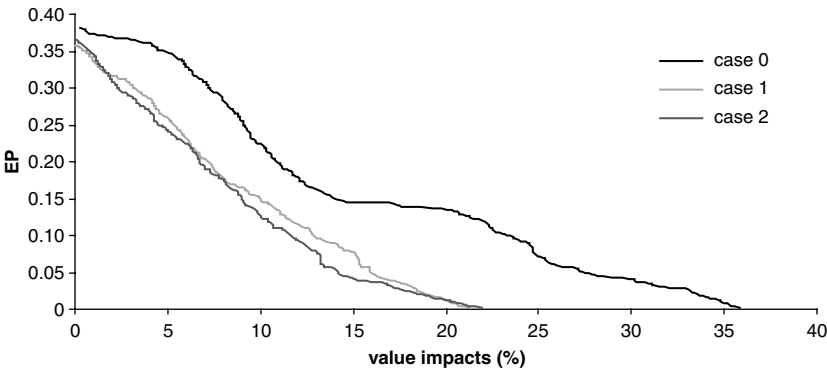
As stated above, farmers temporarily adopt these practices during low rainfall years; however, the scenarios analyzed here assumed that such practices are used during all years. The results were compared with the baseline where no irrigation water was available for maize, jowar, groundnut, and sunflower (case 0), a typical real-life situation during the years of normal rainfall or minor drought.

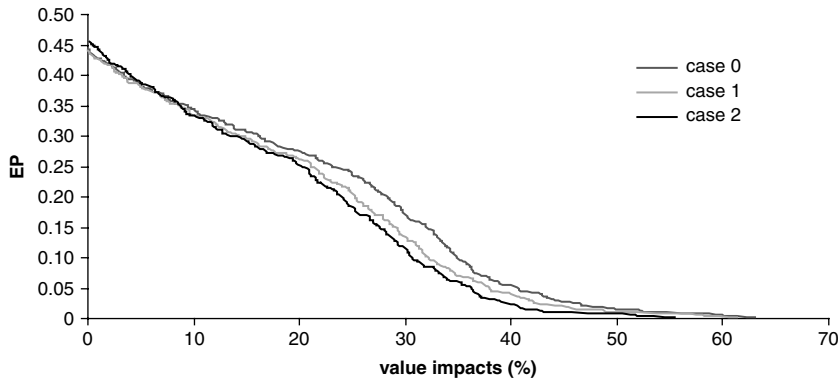
To assess the economic impacts, the changes in yield were converted as changes in product value.<sup>1</sup> The economic impacts were measured as decrease in the loss of VOP (value impacts), where the value impacts are defined with respect to the VOP during normal (nondrought) years.

Alternative uses of irrigation water are compared in figures 4.5 and 4.6. Figure 4.5 shows that in Anantapur a single life-saving irrigation scenario (case 1) was evidently effective, as it decreased the production loss for all drought events. Implementing single irrigation (case 1) would mean that the average loss in production value to farmers across the district would decrease from 24 percent (of value production in normal years) to 14 percent if a 1-in-10-year drought event occurs. The AAL (in value of crop production) across all drought years would be decreased from the estimated 6.7 percent under the benchmark case (case 0) to 3.7 percent under the single irrigation scenario (case 1). Implementing double irrigation (case 2) had little additional impact on crop production loss, bringing it down to 3.4 percent.

These scenarios considerably increased the long-term average annual VOP across all drought and nondrought years. The average annual value

**Figure 4.5. Reducing Cultivable Rice Area in Anantapur: Value of Production LEC**



**Figure 4.6. Reducing Cultivable Rice Area in Mahbubnagar: Value of Production LEC**

gain was estimated at 32 percent under the single irrigation (case 1) and 47 percent under the double irrigation (case 2) scenario. Therefore, the strategy of partially reallocating water from rice cultivation to provide life-saving irrigation to less water-intensive crops in Anantapur would reduce by half the AAL of the overall crop production value during the drought years and would increase the all-year average annual crop production value by one-third for single irrigation and by almost half for double irrigation.

In Mahbubnagar, this strategy is much less effective (figure 4.6). Implementing the single irrigation scenario can lead to a 3 percentage point decrease in value impacts under drought events with return periods between 4 years (25 percent frequency) and 10 years (10 percent frequency). As in Anantapur, adding the second irrigation scenario does not make a difference to loss reduction.

The reason for a greater benefit in Anantapur than in Mahbubnagar can be attributed to the greater proportion of cultivable land for the rain-fed crops with respect to rice. In these simulation runs, a simple allocation based on current land use was used to distribute area to rain-fed crops. The results presented illustrate the model's capability (as well as its limitations) and help formulate options for further investigation.

The model currently assesses the effect of switching to the four rain-fed crops only. However, research conducted by ANGRAU, Hyderabad has shown that more complex crop systems and varieties are likely to be needed (box 4.3). These and other options can be built in and assessed by the model in the future.

**Box 4.3**

**Farm-Level Adaptation Strategies: Expert Recommendations Regarding Cropping Patterns**

In drought-prone areas, cultivation of a single crop is risky, and, hence, intercropping systems need to be advocated. The following intercropping systems are recommended for drought-prone areas of Andhra Pradesh by experts from the Agricultural University.

Soils	Cropping system
Black soils	Cotton + green gram (1:2)
	Cotton + soybean (1:1)
Red soils	Groundnut + red gram (7:1 or 11:1)
	Groundnut + castor (7:1 or 11:1)
	Bajra + red gram (2:1)
	Setaria + red gram (5:1)
	Setaria + groundnut (2:1)

Crop varieties also need to be adjusted by soils, as described below:

Soils	Crops	Varieties
Red soils	Sorghum	CSV-15, CSV-13, CSH-13, CSH-14 Palem sorghum hybrid 1.
	Groundnut	Vemana, Tirupati-1
	Green gram	MGG-295, LGG-450, AMG-275
	Red gram	Palnadu, PRG-100
	Horse gram	Marukulthi-1, AK-26
	Cowpea	Local
	Pearl millet	Anantha, ICMS-451
	Castor	Aruna
Black soils	Cotton	Narasimha, Aravinda, L-604
	Sorghum	NTJ-1, NTJ-2
Black soils	Cotton	Narasimha, Aravinda, L-604
	Sorghum	NTJ-1, NTJ-2
	Setaria	Krishnadevaraya, Narasimharaya Lepakshi, Prasad

***Changes in tillage practice***

Another suggested water conservation practice is to minimize tillage, which in turn reduces the exposure of moist soil at planting time to drying conditions. The effectiveness of minimum tillage as a water conserving effect was



investigated via the EPIC model. Simulations comparing no-tillage with alternative tillage techniques using a moldboard plow and offset discs were done for several crops (groundnut, maize, and rice) and several districts using recorded rainfall and weather conditions from 1979 to 1998.

The results showed that water retention was enhanced slightly early in the season, but these effects had little impact over the entire season. Across all treatments yields only rarely varied by more than 1 percentage point. Minimum till cropping may have other advantages such as in maintaining soil structure and nutrients and in saving energy used for plowing (although it often requires additional herbicide treatments), but it appears to have little effect as a drought mitigation method.

## **Impact of Climate Change**

Greenhouse gas emissions, largely driven by human activities, are already affecting the current climate and will do more so in the future. Most parts of the earth are becoming warmer, and, overall, precipitation is increasing. However, rainfall is projected to become more variable with fewer rainy days but heavier rainfall events in most regions, consequently causing a greater risk of both droughts and floods (Watson 1998; McCarthy 2001).

Thus, climate change is likely to increase the climate variability experienced by farmers. Some factors, such as increased temperatures and longer drought periods, are likely to decrease production, while others, such as the higher concentrations of carbon dioxide in the atmosphere, would increase productivity. The study explored the effects of a feasible climate change scenario on climate variability and agricultural productivity for the drought-prone districts of Andhra Pradesh.

### ***Climate modeling***

The main tool for making projections of climate change is global climate (or circulation) model(s) (GCMs), which simulate climate at a scale of about 300 km by 300 km over India. Higher resolution projections are obtained by running regional climate models (RCMs) for subregions of the globe (often about 5000 km by 5000 km). The RCMs use the output from the GCMs to provide the climate at the boundaries of the region but then simulate the climate within the region at a scale of 50 by 50 km, with some coming down to 20 by 20 km.

Most models fail to simulate some important aspects of the Indian climate. However, recent GCMs have improved significantly; RCMs are relatively better. In making projections of future climate, the climate models are simulated for assumed conditions (that is, greenhouse gas,

particulate composition, concentration in the atmosphere, and so on) for some period in the future, and these results are expressed as a difference from the simulated climate for the baseline period.

For one of the most commonly used scenarios of global development (IS92a scenario), the range of GCMs predict an increase in temperature of 3°–6°C and an increase in rainfall of 15–40 percent by 2100 for India as a whole with high percentage increases occurring mainly in the drier regions and thus of little impact. However, the impacts vary considerably by region.

### ***Climate projections for Andhra Pradesh***

In Andhra Pradesh temperatures are projected to increase by at least 3°C throughout the state by 2041–60. This increase will occur during all seasons of the year. While rainfall is projected to increase for India as a whole, it is projected to decrease in the drought-prone areas of Andhra Pradesh. This decrease would be 5–20 percent during the critical monsoon season with a 5 percentage point increase during the dry March–May period. The number of rainy days appears to decrease by about 5–10 percent. Rainfall intensity (millimeters rain per wet day) appears to remain roughly constant over the years, but there may be seasonal changes that do not show up in the published data as GCMs are still unreliable in predicting rainfall intensities.

Hydrological modeling suggests a significant reduction in runoff (from about 150 millimeters to 110 millimeters per year) in the Pennar River basin. This implies serious problems for water supply in the southern Andhra Pradesh. The overall assessment for the drought-prone regions of Andhra Pradesh for 2041–60 is “chronic water scarcity and drought conditions.”

### ***Simulation of impacts on yields***

In this study, a RCM for India, Hadley Regional Model 2, was used to derive projected climate change for southern Andhra Pradesh for 2050. Two simulations of climate change were generated based on these results by changing the WXGEN within EPIC. Both scenarios assumed an increase in temperature and a decrease in the number of rainy days. The second assumed a more severe reduction in rainfall during the early monsoon months than the first (box 4.4). The results were based on 20 years of simulated weather scenarios.

The impact on crop yields derived for the two most drought-prone districts, Anantapur and Mahbubnagar, is the combined effect of increased temperature, decreased rainfall, and increased carbon-dioxide (table 4.2.).

**Box 4.4****Climate Change Scenarios**

The following scenarios were simulated over the next 20 years under the probabilistic drought risk model:

*Climate change scenario 1:*

- Maximum temperature increases by 2°C
- Minimum temperature increases by 4°C
- Annual rainy days decrease by 5 percentage points
- Atmospheric carbon dioxide at 550 ppm

*Climate change scenario 2:*

- Maximum temperature increases by 2°C
- Minimum temperature increases by 4°C
- Annual rainy days decrease by 5 percentage points
- Cumulative June–September (monsoon) rainfall decrease by 10 percentage points
- Atmospheric carbon dioxide at 550 ppm

There was a minor difference in crop yields between the two scenarios. All four rain-fed crops showed increased yields under climate change scenario 1 and, with the exception of sunflower, a little change in climate change scenario 2. Rice showed a decrease in yield by 8–9 percentage points. Previous studies (Aggarwal et al. 2001) using similar climate change scenarios have suggested a smaller decrease in rice yield of about 5 percent. The model used in this study needs to be analyzed in more detail to determine whether it properly captures the known sensitivity of rice to increases in carbon dioxide concentration in the air

**Table 4.2. Crop Yield Changes Under Climate Change Scenarios: Average Results for Anantapur and Mahbubnagar**

<i>Crops</i>	<i>Average crop yield change with respect to baseline</i>		
	<i>Baseline scenario</i>	<i>CCS1</i>	<i>CCS2</i>
Rice	2.59 t/ha	–9%	–8%
Groundnut	0.97 t/ha	2%	0%
Jowar (Sorghum)	0.87 t/ha	3%	0%
Sunflower	0.51 t/ha	10%	9%
Maize	2.10 t/ha	3%	0%

*Source:* Simulations by the study model.

*Note:* CCS1, climate change scenario 1; CCS2, climate change scenario 2.

(yield enhancing) and increased temperatures at critical times in its growth cycle (yield depressing).

While acknowledging all the uncertainties and the need for further research, the results suggest that climate change would further reinforce the benefits of shifting from rice to less water-intensive crops.

## **Implications for Agriculture Financing and Risk Insurance**

Cost-effective risk mitigation measures cannot always fully protect farmers against drought risk, particularly against extreme events. Risk financing arrangements, such as insurance, can thus help farmers to transfer the residual (nonmitigated) risk. The findings of this study showed a very high variability of losses across time, locations, and crops, a potential to significantly reduce average loss through certain adaptation strategies, and useful implications for designing drought risk financing strategies at the state level, such as innovative insurance products.

The probabilistic drought risk model developed in this study was based on sophisticated weather, soil, and crop growth information. It can be used to forecast the expected yield and loss ratio function over the crop season. The model provides a foundation for reconsidering agricultural insurance through catastrophe modeling techniques.

One of the main reasons why crop insurance has so far been underdeveloped worldwide is the complexity of risk and the lack of adequate risk modeling technology to understand the impact of agricultural risks, particularly drought, on crop yields. As shown in this study, drought is a highly location- and crop-specific phenomenon. The probabilistic drought risk model may thus create new growth opportunities for commercial agricultural (crop) insurance, which until today is almost nonexistent. As mentioned above, developing a capability to simulate the behavior of single farmers would be another important step in this direction.

Crop insurance is a sophisticated line of business, as the impact of adverse natural events such as drought on crop yield is the result of complex agro-meteorological phenomena. This prototype model offers a new risk modeling technology for the design and pricing of crop insurance and particularly weather insurance products recently offered on a pilot basis in India (box 4.5). The probabilistic drought risk model, building on a prototype developed for this study, also offers crop insurers the opportunity to make better informed decisions, as the model can

identify high-risk crops and areas, to better plan reserve requirements and reinsurance needs, and to build a more diversified crop insurance portfolio.

The analysis also highlights that while risk financing arrangements offer farmers a valuable opportunity to finance their losses, it is important to ensure that they do not perpetuate the current situation of farmers'

#### **Box 4.5**

#### **Weather Insurance in India: Advantages and Caveats**

The analysis of the Indian Crop Insurance Program between 1985 and 2002 revealed that rainfall accounted for nearly 90 percent of total claims in India; that is, 75 percent due to deficit rainfall and 15 percent due to excess rainfall. Against this background, crop insurance may be a viable risk financing solution to help farmers to absorb their potential losses. However, traditional multiperil crop insurance suffers from many shortcomings: moral hazard, leading to high claims; adverse selection of risk by taking undue advantage of the system; involvement of multiple agencies and huge administrative cost of running the programs, hidden in Government budgets; lack of reliable methodology for estimating and reporting crop yields; and lengthy process of claims settlement.

Index-based insurance is an alternative form of insurance where indemnities are based on an index (for example, rainfall) and not on individual losses. Rainfall insurance has many advantages, particularly when dealing with small and marginal farmers heavily exposed to drought. Trigger events (such as adverse rainfall) can be independently verified and measured. Since India has an independent rainfall reporting system (through the Indian Meteorological Department), rainfall can be measured in the most tamper-proof environment. This would greatly neutralize moral hazard in data procurement. Rainfall insurance does not encourage potential negligence in the insured, and the cultivator's urge for a good harvest remains unaffected. Rainfall insurance is less expensive to operate because very few agencies are involved in implementation. Rainfall insurance allows for speedy settlement of indemnities, as claims can be settled as early as a fortnight after the indemnity period.

Rainfall insurance was launched as a pilot scheme in June 2003 in Mahbubnagar, district by ICICI-Lombard through the Krishna Bhima Samruddhi local area bank. In 2004, three insurance companies (AIC, IFFICO-Tokyo, and ICICI-Lombard)

*(Continued)*

offered rainfall-based insurance products in several states. They insured 7,181 farmers covering a sum insured of Rs. 157.0 million, earning a premium of Rs. 8.9 million.

However, such a risk-financing product may have limitations in the long term, particularly if the insured crops become increasingly exposed to drought because of a falling groundwater table (or increased rainfall variability caused by climate change). An increase in the frequency and/or the severity of droughts would make rainfall insurance more expensive, as insurers will include this risk increasing effect in the pricing of their insurance products. Rainfall insurance may thus give farmers the wrong incentives to grow nonviable crops rather than providing an incentive to switch to more sustainable farming practices. These incentives may even be stronger if rainfall insurance is eligible for Government subsidies.

heavy dependency on rainfall. A sizable average crop output loss owing to drought, assuming no change in the current agricultural practices, would make such insurance products unviable. Rather, new financing products should provide an incentive to permanently switch to alternative, more sustainable, agricultural and economic practices, such as less water-intensive crops (particularly high-value cash crops), livestock, or some agro-processing activities. Developing contingent financing schemes that could facilitate this transitional drought adaptation process appears an important area for further work.

Two lines of possible innovative financing products are suggested by the study.

- Drought adaptation insurance could provide coverage against risks owing to a shift from nonviable farming business to viable (agricultural and nonagricultural) businesses. This insurance product would thus protect farmers against new sources of risks resulting from a change in their familiar farming practices toward those that are more drought-resilient and less water intensive.
- Drought adaptation credit could provide initial capital to shift to a long-term viable business. In the event of an unexpected loss caused by a failure in the adaptation investment, repayments may be postponed or (partially) forgiven.

These financial arrangements for drought adaptation would try to induce farmers to shift from farming practices that are known to be unviable in the long term because of increasing water scarcity in Andhra Pradesh, to be likely exacerbated by global climate change. These arrangements would offer farmers the opportunity to share new risks, associated with the transition, with the society, because the adaptation process would benefit both farmers and the society.

**Note**

1. Commodity prices are the following: rice: 5,654 Rs/MT; jowar (sorghum): 3,130 Rs/MT; maize: 2,763 Rs/MT; groundnut: 9,647 Rs/MT; and sunflower: 11,900 Rs/MT.





## CHAPTER 5

# Managing Economic Impact of Drought at the State Level

Historically, drought has caused direct and indirect economic, social, and environmental problems in Andhra Pradesh. Drought-induced economic losses include those resulting from impaired agricultural products, excessive demand of power for agricultural water pumping (which is heavily subsidized), decrease in agriculture-dependent industries, and increased unemployment in agriculture and other drought-affected industries. It is difficult to quantify indirect economic losses associated with droughts, as the impacts are generally nonstructural and spread over large areas.

### **Assessment of Direct and Indirect Loss Potentials: Benchmark Case**

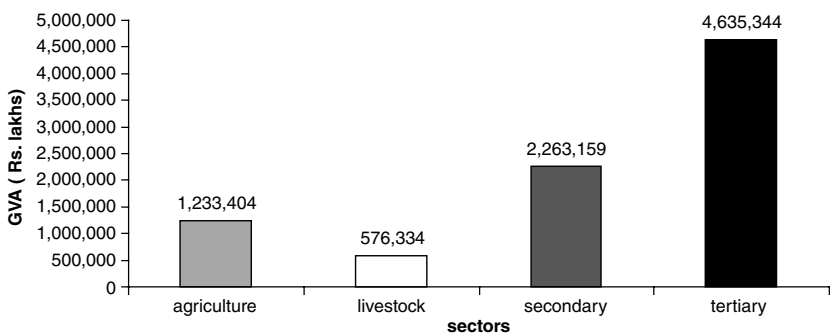
A prototype macroeconometric model was developed to capture the impact of drought at the state level through its impact on the eight selected drought-prone districts. These districts are estimated to account for 70 percent of a state-wise average loss in the agricultural production owing to drought and for 88 percent of the state-wise crop production variability (see chapter 3). This model intended to estimate the impact of drought on the main economic sectors of Andhra Pradesh: agriculture, livestock, and secondary and tertiary sectors.<sup>1</sup>

The macroeconometric model was linked to the damage assessment module that simulates crop production losses caused by droughts in the eight drought-prone districts. “Losses” mean a reduction in the simulated values that the same indicators would have under normal (nondrought) weather conditions.

Under normal weather conditions, the average annual VOP of the five crops in the eight selected districts was estimated at Rs. 262,483 lakhs based on 2002–3 prices. The macroeconometric model estimated the GVA in each sector of the economy during normal years (figure 5.1). The tertiary sector GVA represented 50 percent of total GVA, and the share of the agriculture and livestock sector was 20 percent.<sup>2</sup> These estimates are close to the current economic structure of Andhra Pradesh. In 2002–3, the agriculture and livestock GVA and the tertiary sector GVA accounted for 24 percent and 47 percent of total GVA, respectively.

From the assessment of the crop production losses in the eight districts (see chapter 4), the macroeconometric model translated the impact of these crop losses on the economic sectors of Andhra Pradesh, measured in terms of loss in GVA, as described in chapter 3. The model predicts that a 1 percentage point loss in this VOP would cause 0.25 percentage point loss in the state agriculture sector GVA; a 1 percentage point loss in agriculture GVA in turn would cause 0.24 percentage point loss in the livestock GVA. A 1 percentage point loss in agriculture GVA of the previous year would generate 0.37 percentage point loss in GVA in the secondary sector and 0.19 percentage point increase in GVA in the tertiary sector (with a one year lag).

**Figure 5.1. Average Sectoral GVA For Normal Years**



**Table 5.1. Assistance Provided to Drought Affected States from National Calamity Contingency Fund**

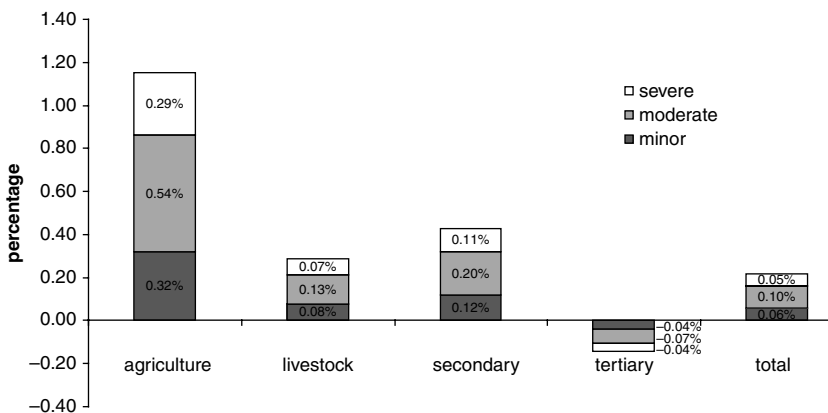
State	2001–2		2002–3		2003–4	
	NCCF (Rs in crores)	Foodgrains (lakh MTs)	NCCF (Rs in crores)	Foodgrains (lakh MTs)	NCCF (Rs in crores)	Foodgrains (lakh MTs)
Andhra Pradesh	—	21.50	123.51	20.00	50.58	18.20

Note: NCCF, National Calamity Contingency Fund; —, not available.

The latter suggests that droughts may have a positive impact on the tertiary sector in the next year. This is consistent with the historical data on performance of the tertiary sector in drought and nondrought years.<sup>3</sup>

A number of factors may account for the drought-related boost to tertiary sector production: central government transfers, changes in consumption patterns caused by the drought, and an increased supply of labor. Table 5.1 shows that the GoI transferred Rs. 153.5 crores to Andhra Pradesh through the National Calamity Contingency Fund in the drought year 2002–3 (*Lok Sabha* Unstarred Question No. 151 2004).

Figure 5.2 shows the long term AAL in GVA caused by droughts as percentage, by the main economic sectors and the contribution of each drought category (minor, moderate, and severe, as defined in chapter 3). Notably, the AAL in GVA for the overall state economy is estimated at

**Figure 5.2. Average Annual Loss as Percent of GVA Owing to Droughts**

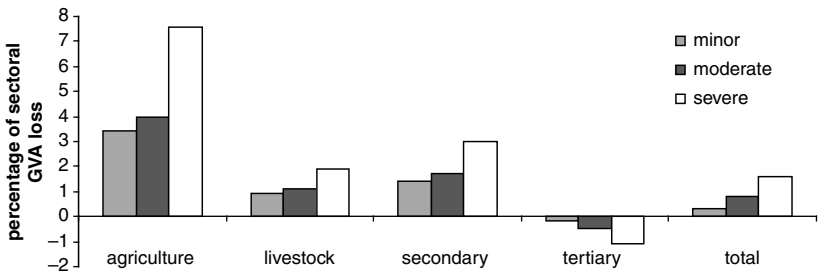
a very modest 0.2 percent, jumping to more than 1 percent for the agriculture sector. The largest average damage appears to be caused by moderate droughts, which contribute almost 50 percent to the AAL in the agricultural sector.

When a minor drought occurs, the conditional average loss is estimated at more than 3 percent of agriculture GVA but below 1 percent of livestock GVA. During moderate drought the conditional average loss in the agricultural sector would be about 4 percent of agriculture GVA and that for the whole economy was 1 percent of total GVA. During severe drought, the conditional average loss approaches 8 percent in the agricultural sector and 2 percent for the whole economy; the tertiary sector, however, showed a gain of 2 percent (figure 5.3).

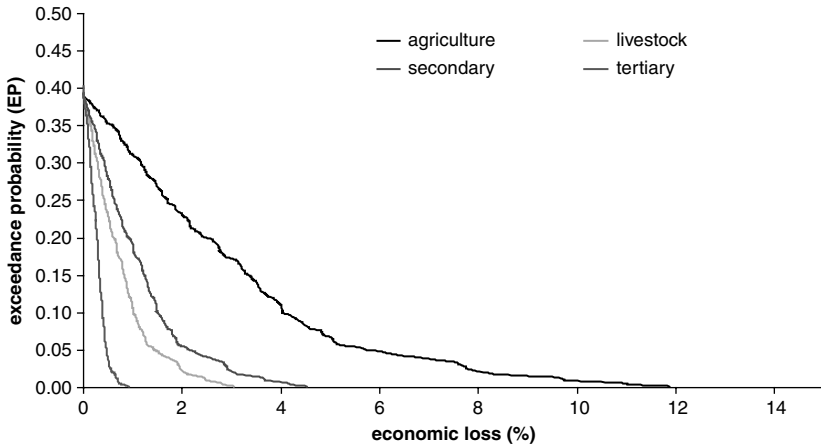
The economic impact of drought events can also be captured through the EPCs (figure 5.4). A moderate drought event (occurring 1 in 10 years in the study region) would cause 4 percent GVA loss in the agricultural sector, 1.5 percent GVA loss in the secondary sector, and 1 percent GVA loss in the livestock sector. During severe drought, which is a rare event, these losses would increase to 7 percent for the agriculture sector, 3 percent for the secondary sector, and 2 percent for the livestock sector. Similar to the GVA analysis on figure 5.3, the secondary sector is more exposed to drought owing to its interdependence on the agriculture sector than the livestock sector.

The analyses presented in figures 5.3 and 5.4 show that drought events in the eight selected drought-prone districts mainly affect the agricultural sector at the state level, with modest losses in the livestock and secondary sectors. Thus, the indirect economic losses outside of the agriculture sector appear limited, or may even generate (marginal) gains in the tertiary sector. The total impact on the Andhra Pradesh

**Figure 5.3. Conditional Average Loss in GVA, by Sector and Drought Category**



**Figure 5.4. Economic Losses, in Sectoral GVA, Caused by Droughts, Andhra Pradesh: EPC**



economy, as measured through the loss in total GVA, is marginal. This finding is consistent with a growing body of evidence on the macroeconomic impact of climate-related disasters. Based on worldwide historical data, a recent study showed that the maximum impact of drought is 0.8 percent of GDP annually for a group of developing countries (Raddatz 2005).

This analysis focused on the macroeconomic impact of drought in Andhra Pradesh. It did not capture the impact of drought on the Government's revenue and expenditure (that is, its fiscal impact). The state fiscal deficit (total revenue – revenue expenditure – capital outlay – net lending) increased by 7.6 percentage points in 2003–4 following the drought year 2002–3.

It is useful to compare the statewide economic impact of drought with those resulting from other climate extremes. A World Bank study focused on cyclones and floods in Andhra Pradesh, using a modeling framework that applies to rapid onset disasters (box 5.1). Interestingly, the AAL for the Andhra Pradesh economy (measured in terms of loss in GVA) caused by droughts is lower than that caused by cyclones or floods, although any comparison has to be made with caution because losses are not measured using the same unit (loss in GVA for droughts and property loss in public infrastructure and housing for cyclones and floods).

**Box 5.1****Financing Rapid Onset Natural Disaster Losses in India**

Given India's vulnerability to growing losses caused by natural disasters at the central and state levels, the World Bank undertook a detailed review of India's catastrophe exposures. The goal of this project was to examine the loss potentials from rapid onset natural disasters and to consider the opportunity to apply enhanced country and state level risk management techniques, with a particular emphasis on the financing of post disaster reconstruction and the efficient allocation of public funds.

The study analyzed and quantified the impact of historical and probable future natural catastrophes on four states (Andhra Pradesh, Gujarat, Orissa, and Maharashtra) that suffered extensively from natural disasters in the recent past. The key major objectives were to create a reasonably comprehensive exposure database for residential buildings and public infrastructure, assess the nature of hazards affecting the region, measure the exposures and vulnerability of districts/blocks in the region to catastrophic shocks, construct hazard maps based on the severity and frequency of hazards involved, and develop an "actuarially sound" flexible economic loss model that could be used for catastrophe risk-management at the state level.

Owing to limited availability of data, the scope of the modeling with regard to potential losses was limited to public infrastructure (consisting of educational, medical building, roads, and bridges) and housing (residential dwellings). Government buildings, utilities, minor irrigation systems, and commercial/industrial property were not included in the study, thus translating into lower damage estimates than would be expected in practice.

The selected perils for Andhra Pradesh were cyclones and floods. The AAL was estimated at US\$61.2 million for cyclones and US\$21.7 million for floods. The PML for a 1 in 150 year event was US\$911 million for; cyclones US\$191 million.

*Source:* Gurenko and Lester (2003).

## **Simulating the Impact of Structural Changes in the Andhra Pradesh Economy**

The economic structure of Andhra Pradesh has profoundly changed over the past two decades, with a decrease of the primary sector (particularly agriculture) and an increase of the secondary and tertiary sectors. Such a

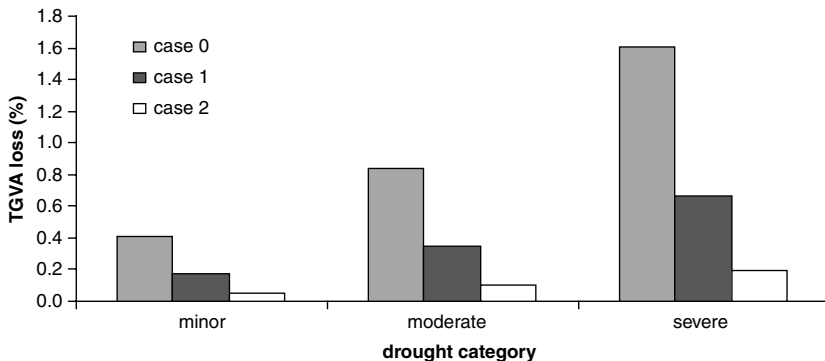
**Table 5.2. Scenarios on the Structure of the Andhra Pradesh Economy, Percent**

<i>Scenario</i>	<i>Agriculture</i>	<i>Livestock</i>	<i>Others</i>	<i>Primary sector</i>	<i>Secondary sector</i>	<i>Tertiary sector</i>
Case 0	14	6	6	26	25	49
Case 1	7	6	6	19	21	60
Case 2	4	6	6	16	17	67

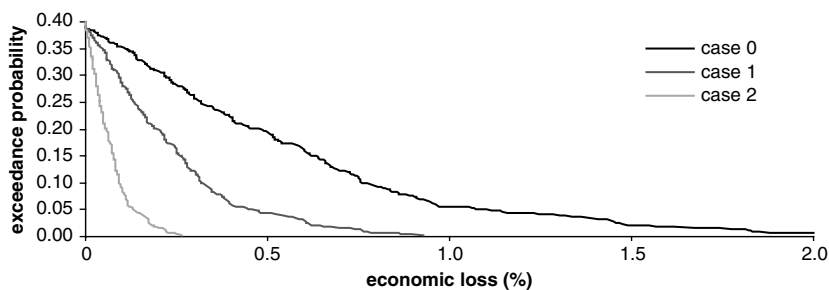
structural change is likely to continue in the future, and can be interpreted as a macroeconomic drought adaptation strategy, since the secondary and tertiary sectors are only marginally affected by droughts.

The impact of the economic structure of Andhra Pradesh on its resilience to drought is examined through several scenarios in the macro-econometric model (table 5.2). The baseline case 0 scenario represents the current economic structure (in terms of GVA). Alternative scenarios, cases 1 and 2, assume that the share of the agricultural sector decreases, while the share of the tertiary sector increases significantly.

The impact of the structural change, as a macroeconomic risk mitigation strategy, on the Andhra Pradesh economy appears to be very effective and able to reduce the loss in total GVA by about three times in case 1 to eight times in case 2 (figure 5.5). Such loss reductions were similar (proportion-wise) for each drought category. Under severe drought, loss in total GVA would decrease from 1.6 percent if the Andhra Pradesh economy maintains the current structure in (case 0) to a mere 0.2 percent in a hypothetical case (case 2) of an economy roughly approximating the current structure of the economy of Brazil.

**Figure 5.5. Loss in Total GVA Under Different Economic Scenarios, by Drought Category**

**Figure 5.6. Losses in Total GVA Caused by Droughts Under Different Economic Scenarios: EPC**



Under the current economic structure (case 0), there is a chance (of about 5 percent) that economic loss (measured in GVA) owing to drought will exceed 1 percent of total GVA in a particular year. The maximum possible impact owing to a major drought is below 1 percent of total GVA in case 1 and well below 0.5 percent in case 2 (figure 5.6). Thus, the macroeconomic impact of drought events occurring in the eight most drought-prone districts of Andhra Pradesh is limited at the state level (in terms of loss in the total GVA), and the reduction in the share of the agricultural sector in the total GVA would make this drought impact even smaller.

However, while the impact of drought averaged over a series of drought and nondrought years may be marginal at the state level, its effect at the farm level in the drought-prone districts can be significant or even disastrous, as discussed in chapter 4. Furthermore, the agricultural sector is the major employment generator for the state. Therefore, any external shock to the agricultural sector has a direct impact on the state's employment scenario, with major social and political ramifications. The total employment loss for 2002–3 because of the loss in the agricultural VOP is estimated at more than 44 lakhs. This highlights the need for effective strategies that specifically target economic indicators that are most vulnerable to drought, such as output and employment in the agriculture sector, particularly in the eight most-affected districts.

### **Socioeconomic Strategies to Decrease Vulnerability to Drought Risk: Issues and Options**

Drought management strategies have been aggressively addressed by the GoAP for many years through a variety of programs (summarized in



chapter 1 and in annex 1).<sup>4</sup> The analysis, performed in this study, provided some additional insights on possible options to better adapt to the drought-prone climate and mitigate the adverse socioeconomic impacts.

### ***Encouraging alternative employment options in the secondary and tertiary sectors***

Loss of employment is a key concern when a sector gets affected because of loss in production. Employment coefficients, obtained from the input-output table (annex 7, table A7.1), provide a measure to account for the loss in employment corresponding to a loss in production. The agricultural employment coefficient for the state was 5.4, which is high relative to other sectors, and confirms the vital importance of the agriculture sector in securing the livelihoods of a large number of people. A one-unit fall in the agricultural output will result in a loss of 5.4 employment units. Thus, the employment profile across various sectors was examined to identify opportunities during drought years.

**Services.** The macroeconometric model estimated that the TGVA of a given year and the AGVA of the previous year are negatively correlated (that is, a 1 percentage point change in agricultural GVA of last year would lead to -0.12 percentage point change in the tertiary sector GVA of the current year). This may be partly due to GoI transfers through the National Calamity Contingency Fund, and movement of labor from agriculture to services. In the service sector, significant employment potential is available in trade and transport (except railways).

**Construction.** This sector had a 49 percent increase in VOP during the severe 2002 drought year probably because of increased Government expenditure as a result of antidrought poverty alleviation programs, hence providing alternative employment to farmers affected by drought. The construction output multiplier obtained from the input-output table was 1.69.<sup>5</sup> Any expenditure in the construction sector would thus lead to an increase in outputs for sectors, such as cement, steel, bricks, and tiles, and additional employment opportunities, which could be of help for drought-affected people.

**Other selected sectors.** Subsectors, such as fishing, mining, and quarrying, increased between 1980 and 1981 and 2002 and 2003. The increase was even greater during the drought years. For example, the share of these sectors increased from 15.9 percent in 2000-1 to 21.6 percent in 2002-3. These sectors have good employment potential, and can absorb some

labor displaced from the agricultural sector, thus moderating the employment loss in the agricultural sector because of drought.

### ***Supporting a structural shift in the primary sector***

***Livestock sector.*** During the drought years of 1993–4 and 2002–3, LGVA increased, although AGVA had decreased in these years. The livestock sector experienced a 77 percentage point increase in production for the drought year of 2002–3 over 1998–9, a normal year. This suggests that drought had no significant effect on the sector. The different components contributing to this sector have behaved differently in the drought year than in the normal year. The three major components of this sector are milk, meat, and eggs. The value of milk as a proportion of the total value of livestock decreased from 55 to 50 percent, while that of meat remained the same. Against this backdrop the value of eggs increased and its contribution almost doubled from 8 to 15 percent. This good performance during drought may also be due to Government interventions that were encouraging the poultry sector.

***Cropping pattern.*** The VOP of the agriculture sector decreased by 27 percentage points in 2002–3. Particularly, the VOP of rice and groundnut decreased by 38 percentage points and 57 percentage points (relative to 1998–9), respectively. This greatly affected the loss of VOP for the total agricultural sector. While the output values of crops like jowar (sorghum), maize, and other food grains showed an increase, the drastic fall in output of rice and groundnut (the major crops grown in Andhra Pradesh that are also much more water sensitive than the other crops grown here) has outweighed the increase in other sectors. The shift from rice and groundnut, particularly rice, to other crops would increase the resilience of the agriculture sector to drought and water scarcity.

Chapter 4 provides a quantitative assessment of decreased production losses from such a shift using the example of two drought-prone districts. The input-output analysis also points to a potential for savings in terms of the inputs required for producing these crops, for example, 30 percent more input is needed for producing 1 unit of rice than for producing 1 unit of maize. During drought the output drops but the inputs for production does not drop in the same proportion as is evident from the input proportions for different sectors under agriculture for 1998–9 and 2002–3.

Therefore, a shift in the cropping pattern from rice to less water-intensive crops, particularly in the eight study districts, is likely to result in both reduced VOP loss and savings in inputs. While this strategy would help decrease the state agricultural GVA loss, its impact would be of particular significance to farmers operating in these districts. This further emphasizes the importance of designing and providing assistance to farmers not only to help absorb the risk of extreme weather events but to promote sustainable agricultural and economic practices in the long term.

## Notes

1. As noted in chapter 3, the validation of the model on the historical data was successful; however, the specification reported here should be considered an initial test product that should be refined in future applications based on additional data and econometrics techniques.
2. Other subsectors of the primary sector (forestry and logging, fishing, and mining and quarrying) represented 6 percent of total GVA.
3. As mentioned in chapter 3, losses/gains in the secondary and tertiary sector must be best viewed as indicative of sectoral linkages, rather than precise estimates, as estimated coefficients are not statistically significant under alternative econometric models. In this case, the current model may slightly overestimate the total losses in GVA.
4. See also India Council of Agricultural Research. 2002. *Drought Management Strategies*. New Delhi.
5. Interpreting the multiplier, a 1 unit increase in the output of the construction sector will result in an additional 0.69 units increase in outputs of other sectors because of interlinkages between the sectors.



## CHAPTER 6

# Conclusions and Recommendations

The key outcomes and conclusions of the study are presented under the following heads for the three study objectives.

- Methodology development (develop a robust analytical framework for simulating the long-term impacts of drought at the micro [drought-prone areas] and macro [state] levels)
- Findings and observations from the quantitative analysis (conduct a quantitative probabilistic risk assessment of the impacts under different scenarios)
- Areas for future action (assist the GoAP in the development of a future-looking and anticipatory strategy for adapting to frequent drought events and conditions of water deficit)

### Methodology Development

Catastrophe modeling is an evolving area, which aids policymakers and other stakeholders in managing risks from natural disasters. The existing models developed by international risk modeling firms focus on the impact of rapid onset disasters, such as earthquakes or hurricanes, on public and private infrastructure. These models have recently been used by the World Bank to develop risk management strategies for financing rapid

onset disasters in India and Colombia. However, slow onset disasters such as drought have characteristics different from rapid onset events and are more difficult to quantify. While they mainly directly affect agricultural output, there are several indirect impacts too. Therefore, an important contribution of this study was in modifying and testing an original model under a different risk assessment paradigm that could be applied to slow onset disasters.

This probabilistic drought risk assessment model is a powerful tool for policy makers to better understand the consequences of drought in the different sectors of the economy, to quantify such impacts with respect to drought severity, and to investigate the economic impacts of risk-coping strategies, both at the farm and state levels. The stochastic dimension included in this model also allows capturing of the underlying uncertainty related to weather events, including the impact of anticipated permanent changes in the global climate. The innovative framework developed in this study, which expands on previous work on catastrophe modeling to drought, can be used to address the issue of drought in other states of India and other drought-prone countries.

The model has a number of specific areas for development to increase its practical value as a planning and decision support tool. The study identified areas, such as:

- *Enhancing the model's capability to be applied at a farm level:* This would allow the model to incorporate more realistic farmer behavior in response to the seasonal patterns of rainfall and the availability of irrigation water. In particular, a more advanced farm-level model would offer the opportunity to look much more closely at the patterns of demand for irrigation, energy, and fertilizers, and for labor.
- *Including a larger number of alternative crops:* Particularly high-value drought-resistant cash crops to assess the benefits of various coping strategies available to farmers.
- *Refining macroeconometric specifications:* Particularly on a larger dataset to increase the predictive power of the model.

Another specialized area for further development and application is re-examination of agricultural insurance through catastrophe modeling techniques. One of the main reasons why crop insurance has so far been almost universally a failure worldwide is the complexity of risk and the lack of adequate risk modeling technology to understand the impact of agricultural risks, and particularly drought, on crop yields. As shown in

this study, drought is highly location-, time- and crop-specific, with crop yield losses that can be decreased further by changing crop and irrigation patterns. The probabilistic drought risk model may thus create new growth opportunities for commercial agricultural (crop) insurance, which is almost nonexistent now.

Some examples of possible future applications of the technical foundation created by this work in the insurance business are:

- *Drought risk model as a risk underwriting and pricing tool:* Crop insurance is a complex line of business, as the impact of adverse natural events such as drought on crop yield is the result of complex agro-meteorological phenomena. This model offers a new risk modeling technology for the design and pricing of crop insurance, and particularly weather insurance products recently offered on a pilot basis in India
- *Drought risk model as an innovative test of economic viability of the agricultural business:* By identifying areas exposed to drought risk and assessing the impact of drought on the crop yield variability, the model helps to determine crops that are economically viable in a particular location under different climate change scenarios. It thus offers a quantitative tool to target subsidies for crops viable in the long term (even if these crops are financially less attractive in the short term).

## Findings and Observations from the Quantitative Analysis

*Despite a variety of antidrought programs, the human and social costs of droughts have been and remain devastating for millions of people in Andhra Pradesh.* Frequent drought is a difficult reality for farmers in the eight rain-shadow districts of Andhra Pradesh. Under the business as usual long-term scenario, the agricultural sector of these districts faces a 40 percent chance (or every two–three years) that the VOP for the five major crops (rice, maize, jowar [sorghum], sunflower, and groundnut) combined will be somewhat less than in a normal rainfall year. Loss of crop production output exceeds 5 percent of the normal year output value every 3 years, 10 percent every 5 years, 15 percent once in 10 years, and 25 percent once in 25 years. The AAL of output caused by drought was 5 percent for the eight districts, ranging from 6 percent in the worst-affected Anantapur district to 3 percent in Prakasam.

Individual farmers may experience greater losses if their specific crops happen to be hard hit. Importantly, for many small and marginal farmers in

these districts, a loss of VOP of 10 percentage points or even 5 percentage points (which is likely to happen quite frequently) can mean falling below the poverty line. This suggests the need for enhancing the existing strategy by innovative, future-looking approaches and tools to help these people adapt to frequent droughts. The GoAP needs to intensify efforts that are sustainable and resilient to water-scarce conditions in the long term to support the economic and social development of drought-prone areas.

*The impacts of droughts are highly variable and localized.* In addition to large variations across time, impacts vary greatly across locations and crops, depending on drought severity. Modeling highlighted significant variations in impacts on a particular crop across districts and even blocks within the same district. For example, severe drought is likely to decrease rice yields from 29 percent in Nalgonda to 62 percent in Kurnool. Yield losses of maize, a rain-fed crop, were particularly staggering in Anantapur, Kurnool, and Mahbubnagar, which are the driest districts with less than 600 millimeters of rainfall every year.

Farmers often rationalize the use of available water by reducing cultivable area under water-intensive rice in favor of less water-intensive crops when there is acute water deficit caused by a major drought. This is however practiced as a temporary measure with the cultivable area of rice typically restored once the drought is over. The model assessed some scenarios of permanently reallocating water from cultivable rice areas to provide 50 millimeters irrigation for the four rain-fed crops (included in the model) at one or two critical stages of their growth. In Anantapur, this strategy helped reduce by half the average annual loss of the overall crop production output during the drought years and increase the all-year average annual crop production output by one-third.

Importantly, better water conservation practices alone (such as a change in tillage practice), without change in cropping pattern, do not appear to have a significant long-term effect on a large scale. The results of the analysis suggest that *losses borne by farmers because of drought can be significantly decreased by adjustments in farming practices that decrease water demand, such as a permanent shift to a larger share of less water-intensive crops in the cropping mix.*

The impacts of measures adopted by farmers are highly location-specific. The same scenario of reallocating irrigation water was found much less effective in Mahbubnagar, where further change in the cropping mix is apparently needed. Even greater disparities in impact and resilience can be expected at the farm and household level.



One of the striking findings of the analysis was that a degree of variation exists for drought impacts on different crops in different locations, clearly suggesting that there is a significant scope for advising farmers about undertaking drought-coping measures, such as switching to alternative crops in response to a poor monsoon.

Since the focus of this study was on linking the district and state-level impacts of drought, the data used in the report was aggregated from the block to the district level (and the total data for the eight districts was mostly used). However, the prototype risk assessment model developed for this study demonstrated good capability for a more disaggregated analysis (including testing a larger number of coping measures) that could be a useful tool to support the development of such plans.

The results suggest that location-specific analyses are needed for informed decision making for the development of effective drought adaptation plans for the affected areas. The analytical capability of the model can be further strengthened as discussed in the model development section above.

*The long-term impact of human-induced climate change reinforces the case for shifting to less water-intensive crops.* Two scenarios of human-induced climate change, based on projections by widely accepted global and regional climate models, were simulated at the district level. While further investigation is needed, preliminary results suggest that climate change would further increase the benefits of shifting from rice to less water-intensive crops.

The impact of drought on the overall state economy, measured as GVA, is modest and decreasing owing to structural changes in the Andhra Pradesh economy. The long-term AAL in GVA for the state owing to all drought events is estimated at 0.2 percent, even under the benchmark (business as usual) case. During the years of severe drought, an event that happens once in about 30–40 years in the eight districts, the loss in total GVA increases to 1.6 percent. The trend of the Andhra Pradesh economy over the past two decades has been a decrease in the contribution by the most vulnerable agriculture sector against an increasing contribution of the secondary and tertiary sectors. As this trend is most likely to continue, the macroeconomic impact of drought will decrease further.

The above findings are consistent with a growing body of evidence on the macroeconomic impact of climate-related disasters; based on worldwide historical data, the maximum annual impact of drought is estimated at 0.8 percent of GDP for a group of developing countries.

*Facilitating an observed structural shift in the Andhra Pradesh economy from the agriculture sector toward the secondary and tertiary sectors could be a powerful macroeconomic drought adaptation strategy.* The impact of such a shift on the economy's resilience to drought was examined through several scenarios in the macroeconometric model, corresponding to different shares of the agriculture, livestock, secondary, and tertiary sectors in total GVA. The analysis revealed that loss in total GVA because of drought events could be decreased by 80 percentage points (for a scenario when the shares of the agriculture, secondary, and tertiary sectors roughly approximate the structure of the economy of Brazil). The loss in total GVA resulting from severe drought in the eight districts could be decreased from 1.6 to 0.2 percent. These encouraging signs in the average macrolevel indicators provide an opportunity for the state to more actively and effectively provide targeted assistance to those whose lives and well-being are devastated by drought.

The impact of droughts is different for different sectors and this knowledge can help in developing sound Government policies. The macroeconometric model showed a significant negative impact of drought on the agricultural sector, a much more limited impact on the livestock sector and the secondary sector, and a positive impact on the tertiary sector. Interestingly, the livestock sector is less affected by drought than the secondary sector. Thus, the future impact of drought on the rural economy can be moderated by promoting the livestock sector, particularly poultry, which performed especially well during recent droughts.

Furthermore, the tertiary sector appears to gain from drought events (with a one-year lag). Several factors associated with drought, such as GoI transfers, changes in consumption patterns and an increased supply of labor displaced from agriculture, may account for the observed boost in tertiary sector production.

*Loss of employment during drought remains a key concern.* The agricultural sector is the major employment generator for the state. The agricultural employment coefficient for the state is 5.4, relatively higher than for other sectors. This implies that a 1-unit loss in output will result in more than 5 units of employment loss. Therefore, any external shock to the agricultural sector will have a strong impact on employment. The total employment loss for 2002–3 linked to the loss in the agricultural output owing to a major drought was estimated at more than 44 lakhs. This highlights the need for strategies that specifically target the most affected drought economic indicators, such as output and employment

in the agriculture sector, and the most vulnerable districts, mandals, and communities.

*A number of opportunities outside of the agriculture sector can mitigate the impacts of drought on employment and income in the short to medium term.* The options that arose from the analysis included the following: (a) in the service sector, significant employment potential is available in trade and transport (except railways); (b) investment in the construction sector would increase employment in this and related (cement, bricks, steel) industries; (c) the labor displaced from the agricultural sector can find employment in the mining and quarrying sectors, thereby mitigating the employment loss in the agricultural sector; and (d) the poultry sector may have good drought risk mitigation potential under local conditions, although all the factors accounting for its strong performance during recent droughts, as well as potential risks to farmers, need to be better understood.

*The impacts of droughts are highly differentiated and poor farmers/households are most vulnerable.* Droughts continue to have a negative impact on the performance of the agriculture sector and thus the lives of the millions of rural poor. A range of impacts were witnessed by a study that surveyed communities in Mahbubnagar, one of the poorest and worst affected districts. While some farmers/households are able to change farming practices or migrate to other sectors, others are forced into starvation, as well as loss of health and even life. These responses reinforce the need for tailored assistance to those in need and addressing immediate problems related to vulnerability of the poor to shocks.

## **Areas for Future Action**

*Develop a multitiered strategy combining statewide economic and sectoral policies with well-targeted efforts at the micro level.* Though drought is a complex and challenging natural phenomenon, it is an even more complex and challenging socioeconomic phenomenon with diverse, sometimes conflicting, impacts on the micro, sectoral, and macro levels. The analysis revealed the stark contrasts through which droughts manifest at different geographic levels, on different economic indicators, on different crops and sectors, on different population groups, and on different measures of human well-being. Thus, an effective strategy to tackle this phenomenon would need to deal with these multiple levels and dimensions in a balanced fashion.

A particular challenge, as always, is to effectively reach out to those poorest and most vulnerable. The reason is that more affluent farmers and households are typically better able to use alternative opportunities, including temporarily changing farming practices or migrating to other sectors, whereas poorer farmers are least resilient to shocks. While far from being exhaustive, this study highlighted some elements of a possible strategy for increasing resilience to drought through adaptation at different levels.

***Continue and accelerate the ongoing changes in the economic structure at the macro level.*** This can significantly contribute to increasing the resilience of the state economy and/or its people to drought in the long term, such as:

- Facilitating growth of the tertiary sector;
- Supporting the development of the livestock sector, particularly poultry, as an important buffer to absorb the drought impacts on rural economy;
- Encouraging the shift in cropping pattern from rice to less water-intensive crops would decrease vulnerability to drought impacts (including reviewing and addressing unfavorable incentives associated with current agricultural input subsidies and rice procurement prices)

***Encourage investments in sectors with significant employment potential for the labor displaced from the agriculture sector,*** such as certain services (trade and transport), construction, mining, and quarrying subsectors. This would moderate the impact of drought on affected communities in the short to medium term.

***Address the growing gap between the encouraging macroeconomic trends and impacts on farmers and communities in drought-prone areas.*** The state economy is well poised to become less vulnerable to rainfall variability. Yet, the same, or possibly a larger number of people, who are (and will be for many years ahead) involved in agriculture, remain at risk of loss of livelihood and opportunities because of drought. Thus, it appears critical to intensify ongoing efforts and initiatives to promote more effective, targeted, and coordinated assistance to those in greatest need.

***Initiate development and implementation of drought adaptation plans for the most affected areas at the micro level (gram panchayat, watershed, mandal).*** The focus should be on measures that promote a gradual

shift to more sustainable agricultural practices (for example, changing cropping pattern in favor of less water-intensive crops) and other economic activities that are less vulnerable to drought (for example, livestock) complemented by water conservation and watershed management activities. Given that the impact of these measures is medium to long term, the plans would also include short-term relief and safety net measures that would help protect the nutritional, health, and educational needs of affected communities. In addition, special measures need to be considered for the poorest segments of the community, such as landless laborers and marginal farmers, who have the lowest adaptive capacity.

The planning process ought to involve participatory approaches tailored to the needs of specific communities and help community members agree on a common strategy for securing stable and sustainable sources of income. This initiative should build upon the existing successful experiences with community-based watershed management in Andhra Pradesh, as well as integrate relevant schemes by different departments.

***Create a supporting institutional and policy framework.*** This planning and implementation process would require commitment from and involvement of all levels of Government (local to state to central), to provide extensive technical assistance and other support mechanisms to farmers and communities. It would need to be supported by adequate institutional arrangements to deliver assistance to communities, an enabling policy framework, an aggressive awareness campaign, massive capacity building efforts for all key stakeholders, and innovative financial schemes that mitigate the risks and startup costs of transition to different crops, technologies, and economic activities.

***Explore innovative microfinancing/insurance schemes for farmers that promote a shift to more sustainable practices.*** Cost-effective risk mitigation measures cannot fully protect farmers against drought risk. Risk financing arrangements can thus help farmers to absorb this residual risk. For example, since 2003 private insurance companies are providing rainfall insurance on a pilot basis. While such innovative risk financing arrangements offer farmers new opportunities to finance their losses, it is important to ensure that they do not perpetuate the current situation of heavy dependency of farmers on rainfall. A sizable average crop output loss because of drought, if there were no changes in the current agricultural practices, would make such insurance products unviable. Rather, new financing products should provide an incentive to permanently switch to

alternative, more sustainable agricultural and economic practices, such as less water-intensive crops (particularly high value cash crops), livestock, or some agro-processing activities. Developing contingent financing schemes that could facilitate this transitional drought adaptation process appears an important area for further work.

Two possible innovative financing products are proposed by the study:

- Drought adaptation insurance, which could provide coverage against risks caused by a shift from nonviable farming business to a viable (agricultural and nonagricultural) business. This insurance product would protect farmers against new sources of risks resulting from a change toward farming practices that are more drought resilient and less water intensive.
- Drought adaptation credit, which could provide initial capital to shift to a long-term viable business. In the event of an unexpected loss caused by a failure in the adaptation investment, repayments may be postponed or (partially) forgiven.

***Develop a Decision Support Toolkit for drought management planning.***

The drought risk model developed by this study, complemented by other tools and methods (such as a real-life drought forecasting system developed by the Central Research Institute for Dryland Agriculture), could provide a good scientific and information basis for supporting drought adaptation and management planning at different spatial levels.

***Facilitate informed public debate on drought adaptation strategies by assessing and disseminating information on the impacts and options.***

It is possible to quantify and conduct an objective assessment of economic losses caused by drought. This information needs to be more effectively disseminated to all the concerned stakeholders to assist with developing a common vision and reaching a broad-based agreement on the program of action.

## **ANNEX 1**

# **Programs Addressing Drought in Andhra Pradesh**

### **Risk Financing Programs**

#### ***Calamity Relief Fund***

This fund was established separately for each state based on recommendations of the IX Finance Commission and has since been approved for continuation by the X and XI Finance Commissions. This fund should be used for meeting the expenditure and for providing immediate relief to the victims of cyclone, drought, earthquake, fire, flood, and hailstorm. Table A1.1 describes the financial status of this fund over the past five years.

#### ***National Calamity Contingency Fund***

This fund came into effect in 2000–1 and continued to be in operation until the end of the financial year, 2004–5. National calamities caused by cyclone, drought, earthquake, fire, flood, and hailstorm are considered to be of severe nature requiring expenditure by the state Government in excess of the balance available in its own Calamity Relief Fund to qualify for relief assistance under the National Calamity Contingency Fund scheme. The initial corpus of the National Fund is Rs. 500 crores provided by the

**Table A1.1. Calamity Relief Fund for Andhra Pradesh, 2000–5 (Rs in Lakhs)**

<i>Share of</i>	<i>2000–1</i>	<i>2001–2</i>	<i>2002–3</i>	<i>2003–4</i>	<i>2004–5</i>	<i>Total</i>
Center	14854	15597	16377	17196	18056	82080
State	4951	5199	5459	5732	6019	27360
<b>Total</b>	<b>19806</b>	<b>20796</b>	<b>21836</b>	<b>22928</b>	<b>24074</b>	<b>109440</b>

Government of India. The National Centre for Calamity Management, constituted by the Ministry of Home Affairs, Government of India, monitors the occurrence of natural calamities relating to cyclone, drought, earthquake, fire, flood, and hailstorm on a regular basis and assesses their impact on area and the population. Assistance from the National Calamity Contingency Fund is only for immediate relief and rehabilitation. Any reconstruction of assets or restoration of damages is financed through plan funds. The unspent balance of the fund at the end of the financial year 2004–5 will become available to the GoI to be used as a resource for the next plan.

### ***Crop Insurance***

The National Agriculture Insurance Scheme was implemented in Andhra Pradesh in 1999–2000. A state has the discretion to identify the areas and crops to be covered. Once the specific area-crop combinations have been notified, participation is compulsory for farmers in those areas cultivating the specific crops and taking agricultural loans. For farmers who take loans the sum insured may be at least equal to the crop loan advanced. All farmers can insure up to the value of the threshold yield of the insured crop.

Eighteen crops are currently insurable under this scheme during Kharif season (for example, rice, maize, sunflower, groundnut, sugarcane, and cotton) and 10 crops during Rabi season (for example, rice, maize, sunflower, and groundnut). The standard area yield insurance scheme has recently been extended to include farm income insurance and rainfall insurance.

The XI Finance Commission noted the need to strengthen the National Agricultural Insurance Scheme to supplement other Government measures to provide relief during a natural calamity.

## **Drought-Proofing Programs**

### ***Drought-Prone Areas Program***

The Drought-Prone Areas Program, a centrally sponsored scheme in operation since 1973, aims at restoring the ecological balance in the drought-prone areas and mitigation of the adverse effects of drought on



crops and livestock through integrated development of natural resources by adoption of appropriate technologies.

The program aims to develop the drought-prone area with an objective of drought proofing by conserving soil-land moisture, building water harvesting structures, and setting up afforestation and horticulture programs on a comprehensive micro watershed basis. So far, 3518 watersheds have been taken up covering 110 blocks in 12 districts covering an area of 17.6 lakh ha. Almost 30 percent of the total watersheds under the program are located in Andhra Pradesh. A total of Rs. 507.57 crores were spent toward implementation of the program from 1995–6 to 2002–3. The central and state Governments share the expenditure for this program in the ratio of 75:25.

### ***Joint Forest Management/Community Forest Management***

The GoAP adopted the Joint Forest Management Program in 1992, which envisages a strategy for production, improvement, and development of forests with the involvement of local communities by forming Vana Samrakshana Samithies. There are 7090 such Samithies actively involved in the protection and development of forests in Andhra Pradesh.

### ***Water harvesting structures***

The Forest Department has taken up large-scale water conservation structures in forest areas under the Neeru-Meeru (Water and You) Program. The structures include continuous contour trenches, check dams, rockfill dams, percolation tanks, and sunken gully pits. Seven phases of Neeru-Meeru have been completed. Water storage capacity of 1566 lakh cubic meters has been created in forest areas.

### ***Microirrigation Project***

GoAP launched a massive Microirrigation Project in 2003–4 throughout the state, with special emphasis on water-stressed mandals. The project envisages installation of sprinklers, drip irrigation, and rain guns to use the available underground irrigation water in the most efficient manner while improving productivity. The first phase aims to cover 2.50 lakh ha, with 50 percent state Government subsidy on the unit cost given to farmers.

### ***Andhra Pradesh Rural Livelihood Project***

This project provides critical support to the ongoing watershed movement in five drought-prone districts in Andhra Pradesh (Anantapur, Kurnool, Mahabubnagar, Nalgonda, and Prakasam). The mandate is to position

livelihood concerns strategically in watershed for the inclusion of women, the poor and the landless. The project, financed by the U.K. Department for International Development, will facilitate people-centered development inputs to the watershed program of the state including 500 new innovative watersheds, sustainable rural livelihood initiatives in 2000 watersheds, capacity building of various stakeholders, research and lesson learning for policy initiatives, and infrastructure support.

### ***Watershed development***

The national Bank for Agriculture and Development finances a watershed development fund. Owing to the watershed development program, the proportion of area under irrigation has increased by 19–29 percentage points among all households. Total employment has gone up by 11–29 percentage points. Yield rates have gone up for irrigated as well as nonirrigated crops. Only 50 percent of the watersheds studied are economically viable in terms of incremental returns. The equity effect is not clearly known, though the impact on rich and medium households possessing lands seems higher. The drinking water situation has improved substantially and groundwater levels improved to a limited extent. Migration of labor decreased during the execution period, though in the majority of cases this was not sustained after the execution period. Household's preference for education increased and the role of women in financial matters improved substantially.

### ***Integrated Wastelands Development Program***

Rapid depletion of green cover and vast stretches of marginal lands lying fallow are causing enormous ecological imbalance. Productivity was negligent because of soil erosion and marginalization of lands. To arrest this, a massive integrated wasteland development was undertaken in 1991 with 100 percent central assistance. The program is being implemented in 17 districts in Andhra Pradesh, with 38 projects covering an area of 362,985 ha.

### ***Rural infrastructure development***

A fiscal package has been developed for rural infrastructure development. In Andhra Pradesh the Department of Rural Development, Forest, Panchayat Raj, Minor Irrigation have availed this scheme. In this program, each district has selected certain villages for treatment. The implementation at village level is through user groups formed based on the drainage

line. These groups decide the treatment of drainage line or common lands. The scheme excludes private land treatment.

## **Employment Programs**

There are many other self-employment programs, based on income generation, to improve the livelihood of the affected population. These programs are based on people's participatory approach. The GoAP has created various employment generation programs to eradicate poverty. While considering self-employment schemes the Government has given priority to mini and micro enterprises. These programs can be considered as mitigation measures at the time of drought.

### ***Sampoorna Grameen Rozgar Yojana***

This has the following objectives:

- To provide additional wage employment in all rural areas and thereby provide food security and improve nutritional levels
- To create a durable community with social and economic assets and infrastructural development in rural areas

The program provides wage employment to women, scheduled casts, scheduled tribes, and parents of children withdrawn from hazardous occupations. The works to be taken up must be labor-intensive, leading to the creation of additional wage employment, durable assets and infrastructure, particularly those which would assist in drought-proofing, such as soil and moisture conservation works, watershed development, and afforestation.

### ***Mission-based approach to employment generation***

The GoAP has established an Employment Generation Mission to coordinate activities of all the concerned departments in employment generation and manpower planning. The mission will prepare a time-bound action plan for implementation. The Government will act as facilitator and would identify and prioritize key sectors with employment potential and ensure successful implementation.

### ***Empowerment of poor women***

The Self-Help Groups of Women (thrift groups) Program has mobilized and organized 48 lakh poor women in the rural areas into 3.7 lakh groups.

These women's groups have built a corpus fund of Rs. 750 crores consisting of their savings, borrowings from banks and the Development of Women and Children in Rural Areas revolving fund from the GoI. The empowerment process has enabled the Development of Women and Children in Rural Areas and thrift group members in addressing all dimensions of poverty. The movement has contributed to the augmentation of incomes, improvement of nutrition, better child-care facilities for poor women, and enhanced status of women in rural households. A similar program for urban areas has now been started under the name of Development of Women and Children in Urban Areas, and 5,523 groups have been formed and developed in urban areas.

### ***Food for work programs***

These programs aim at helping millions of rural poor stave off hunger and unemployment. The basic principle of these programs is to provide employment to the poor during hard times, to create community assets through labor-intensive work, and to pay the laborers in kind (food grains or other food items). In 2005, the Government of India adopted the National Rural Guaranteed Employment Scheme, which guarantees 100 days per years of employment for community works in eligible districts, with the focus on natural and water resource management activities.

### ***Agriculture diversification initiatives***

These include programs by the Department of Agriculture to supply alternative crop seeds to farmers in anticipation of drought, and provide knowledge and other technical assistance for alternative, less water-intensive crops, technologies, and practices (for example, through onsite farmer schools), as well as, recently, price stabilization measures for maize and some other rain-fed crops by the Marketing Department.

## ANNEX 2

# Definitions of Drought

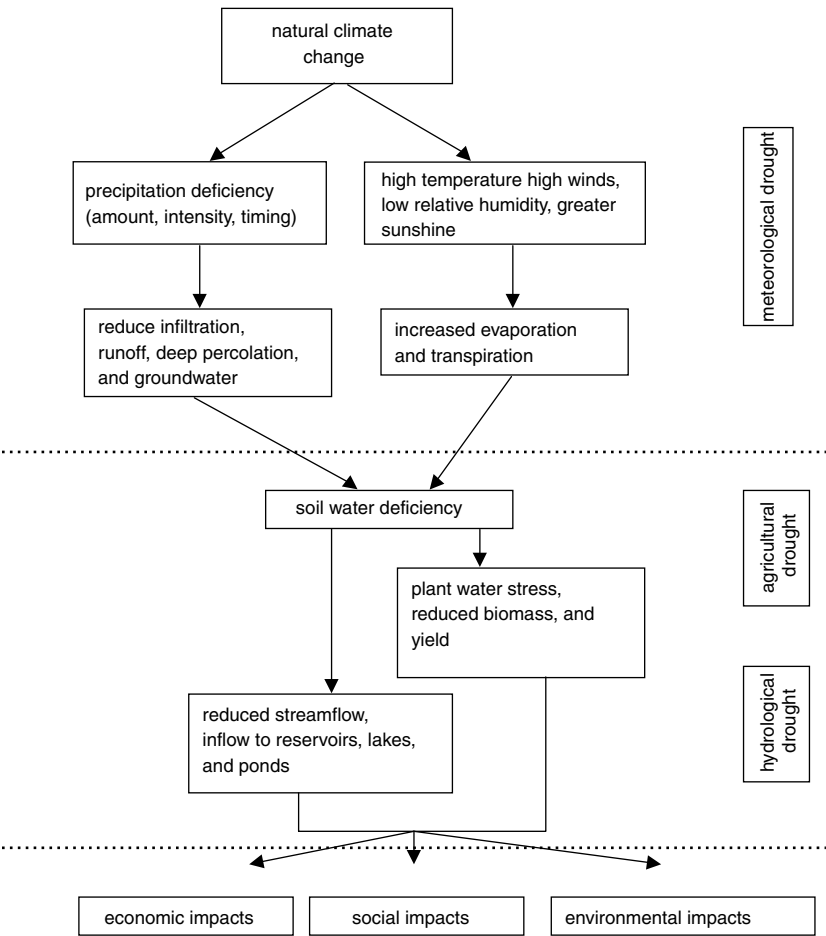
Drought is a normal, recurrent climatic feature. It occurs in almost all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration. It differs from aridity, which is restricted to low rainfall regions and is a permanent climatic feature.

Drought results from a deficiency in precipitation that persists long enough to produce a serious hydrological imbalance. It should be considered relative to long-term average condition of balance between precipitation and evapotranspiration (that is, evaporation and transpiration) in a particular area. Drought differs in three essential characteristics: intensity, duration, and spatial coverage. Intensity is the degree of shortfall in precipitation and/or the severity of impacts associated with the shortfalls.

It is generally measured by the departure from normal of a climatic index and is closely linked to duration in the determination of impact. Impact relates to the timing (for example, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth staged) and effectiveness of rainfall (for example, number of rainfall events). Other climatic factors such as temperature, wind, and humidity can significantly aggravate its severity.

Droughts are categorized as meteorological, hydrological, agricultural, and socioeconomic (Nagarajan 2003). See figure A2.1.

**Figure A2.1. Definitions of Droughts**



Source: National Drought Mitigation Center 2005.

*Meteorological drought:* Defined usually as the degree of dryness (in comparison to some normal or average amount) and the duration of the dry period. Another definition of meteorological drought is identified periods of drought for the number of days when precipitation was less than pre-determined thresholds. The India Meteorological Department uses a meteorological definition of drought based only on rainfall deficiency from the mean annual, mean summer monsoon, mean monthly, and mean weekly rainfall. Thus, meteorological drought is said to occur when

the seasonal rainfall received over an area is less than 75 percent of its long-term average value. It is further classified as moderate drought if the rainfall deficit is 26–50 percent and severe drought when the deficit exceeds 50 percent of the normal. A year is considered a drought year if the area affected by the drought is more than 20 percent of the total area of the country.

*Hydrological drought:* Associated with the impacts of precipitation shortfalls on surface or subsurface water supply (for example, stream flow, reservoir and lake levels, and groundwater). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Hydrological droughts usually occur out of phase with meteorological droughts. Water in hydrological storage systems (for example, reservoirs and rivers) is often used for multiple and competing purposes (for example, flood control, irrigation, recreation, and hydropower), further complicating the sequence and quantification of impacts. Although climate is the primary contributor to hydrological drought, other factors such as changes in deforestation, land degradation, and the construction of dams all affect the hydrological system.

*Agricultural drought:* Links various characteristics of meteorological and hydrological droughts to agricultural impacts. It is related to precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and so on. Plant water requirements depend on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. Agricultural drought should be able to account for the variable susceptibility of crops during different stages of development, from emergence to maturity. Deficient topsoil moisture at planting may hinder germination, leading to low plant populations per hectare and thereby decrease in final yield.

*Socioeconomic drought:* Associated with the supply and demand of economic goods, such as water, forage, food grains, fish, and hydroelectric power. Socioeconomic drought occurs when the demand for an economic good exceeds supply due to a water-related shortfall in water supply.





## **ANNEX 3**

# **Stochastic Crop Production Loss Model**

The stochastic crop production loss model comprises three submodules: the stochastic hazard module, the vulnerability and exposure module, and the loss module.

### **Stochastic Hazard Module**

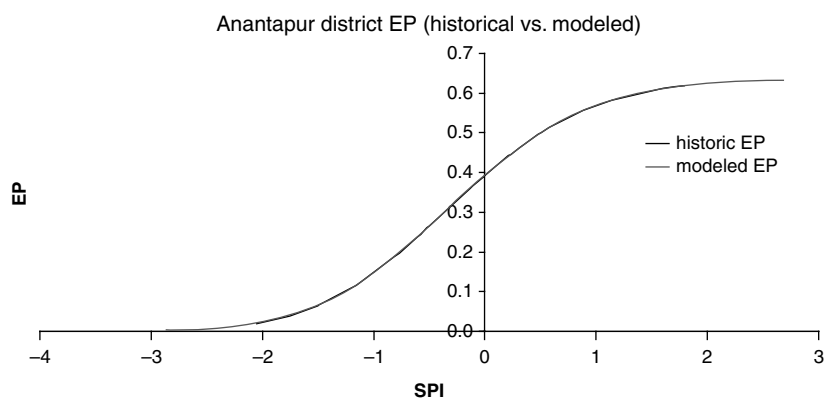
Weather is simulated for 500 years using historical weather parameters for each block with the WXGEN weather simulator (annex 4). Each of the simulated events (years) is assigned a drought category based on the SPI derived from cumulative seasonal (June–December) rainfall (McKee et al. 1993).

The SPI computation for a specific time scale and location requires an historical record of 30 or more years of monthly precipitation. The long-term record is fitted to a gamma probability distribution and is then transformed into a normal distribution (that is, SPI), which, by definition, has zero mean and unit variance. McKee et al. (1993) defined drought as an event that occurs if the SPI value is  $-0.1$  or less, while in the present study the SPI value of  $-0.5$  or less was used to define a drought event. The drought categories as defined in this study are presented in table A3.1.

**Table A3.1. Drought Categories**

<i>Seasonal SPI</i>	<i>Drought category</i>
0.5 to –0.5	Normal year
–0.5 to –1.0	Minor drought
–1.0 to –2.0	Moderate drought
–2.0 to –3.0	Severe drought
–3.0 and below	Extreme drought

**Figure A3.1. Validation of SPI for Anantapur**



An SPI value greater than 0.5 is assumed to represent a year with excess rainfall. SPI is computed for each year at the district and state (eight districts combined) levels by aggregating cumulative seasonal rainfall for all the blocks in the district or state. For aggregation, the simple average of the rainfall of all the blocks is used. Figure A3.1 shows the results of validating the modeled SPI index with historical data for Anantapur.

The rate of occurrence for any event in the 500-event set is assumed to be 1 per 500. Thus, the frequency of a given category of drought among the simulated events is computed as the number of events of the particular category divided by 500.

**Vulnerability and Exposure Module**

In the vulnerability and exposure module the average yield and planting area associated with each of the simulated events is determined for each crop at block level.

The average yield of five crops (jowar, maize, groundnut, sunflower, and rice) associated with each block and category of drought is determined with the help of EPIC model. EPIC runs are made at block level for selected events (10 numbers) representing different categories of drought. The events are selected from the 500-year event set for every block to represent each of the drought categories based on a representative SPI value.

The planting area model computes the planting area associated with each crop and for each of the 500 events at block level based on annual rainfall corresponding to the event.

## Loss Module

In the loss module, the crop-wise loss in production associated with the four categories of drought is computed at the block, district, and state (eight districts combined) levels.

For each crop, production is computed for each of the 500 events at the block level as  $\text{production} = \text{planted area} \times \text{average yield}$ . Block-level production is then summed up to get the production at district and state levels. The average normal production at district/state level is computed as the simple average of production for all the events categorized as normal year in the 500-year event set at the corresponding (district or state) level. Percentage loss in production for each event and crop is then calculated at the required level as:

$$\% \text{ loss in production} = 100 \times (\text{average normal year production} - \text{production for the event}) / \text{average normal year production}$$



## **ANNEX 4**

# **WXGEN in EPIC**

WXGEN in EPIC is based on Richardson's (1981) description. The model generates daily values for precipitation, maximum and minimum temperature, solar radiation, wind speed, and wind direction for any number of years for a location (Sharpley and Williams 1990). The weather generator in EPIC is designed to preserve the dependence in time, internal correlation, and the seasonal characteristics that exist in actual weather data. Precipitation and wind are generated independent of the other variables. Maximum temperature, minimum temperature, and solar radiation are generated depending on whether the day is wet or dry.

A first-order Markov chain is used to generate the occurrence of wet or dry days. For a wet day the precipitation amount is generated based on skewed normal distribution. With the first-order Markov chain model the probability of rain on a given day is conditioned on the wet or dry status of the previous day.

The procedure to generate the daily values of maximum and minimum temperature and solar radiation is based on the weekly stationery generating process of Matalas (1967). The wind component of the model provides for generating daily values of wind speed and direction as described by Richardson (1982).

EPIC can be run using either historical weather data or it can generate some or all of the data via its weather generator. The weather generator parameters have to be based on historical data for the study area. Within the study area, historical daily rainfall data were available at the block level, but other meteorological data were available at district level. The weather generator parameters at the block level are computed using daily rainfall data at block level and other daily weather data at district level.

WXGEN was evaluated for its effectiveness in simulating Indian weather conditions using 20 years of daily weather data from India Meteorological Department stations at the Anantapur and Mahbubnagar districts. The weather generator model parameters for the simulations were calculated from 20 years of daily weather data for Anantapur and Mahbubnagar.

By using the weather generator model parameters, daily weather was simulated for 50, 100, and 200 years for the two stations. A chi-square test was then performed to test whether the simulated monthly means of rainfall, air temperature, and relative humidity are significantly different from those derived from historical records. It was found that simulation convergence is achieved after simulating 200 years of weather and the null hypothesis was rejected at 5 percent level of significance for rainfall and 1 percent for the other parameters.

Consistency among the daily parameters is also verified by performing a *t*-test for regression coefficients between simulated and historical daily values. The test results showed that the model preserved the internal correlation among the variables with a 1 percent level of significance. The WXGEN was recommended for weather generation in this study, based on these results.

There are 450 blocks in the eight selected districts. Data were available for all the blocks up to 2003. Rainfall data were available for 1988–2003 for 60 percent of the blocks. For the remaining blocks, rainfall data were available before 1988, going as far back as 1963. Wherever data were available prior to 1988, the model parameters for those blocks were computed using data before 1988. However, block-level rainfall data were used only for simulation of weather, which required other parameters (temperature, humidity, and so on) as well. Other parameters were taken from district-level India Meteorological Department data available for 1973–99. Thus, the final period used in simulation of weather at block level was constrained by rainfall at block level and other parameters at district level.

Block-level historical daily rainfall data available for the study region were subjected to a number of quality control procedures before computing the block-level rainfall simulation parameters. The spatial and temporal consistency were checked and suspected data points were replaced with nearby stations data. Missing years and daily gaps in the data were not used for the parameter computation.

For computation of return periods of droughts at district level, rainfall data at district level supplied by Directorate of Economics and Statistics for 1973–2003 for all eight districts were used.





## **ANNEX 5**

# **EPIC: Crop Growth Model**

EPIC is a mathematical model that operates on a daily time step to simulate evapotranspiration, soil temperature, crop potential growth, growth constraints (water stress, stress due to high or low temperature, and nitrogen and phosphorous stress), and yield. EPIC uses a single model for simulating all crops. Each crop has unique values for model parameters, which can be adjusted or created by the user if needed provided they have enough knowledge of the crop and model operation. The crop growth model uses radiation-use efficiency in calculating photosynthetic production of biomass. The potential is adjusted daily for stress from water, temperature, nutrients (nitrogen and phosphorous), aeration, and radiation. Crop yields are estimated using the harvest index concept. Harvest index increases as a nonlinear function of heat units from zero at the planting stage to maximum value at maturity. The harvest index may be decreased by high temperature, low solar radiation, or water stress during critical crop stages.

### **Input Data**

Two kinds of standard data sets are required as EPIC inputs files:

- Basic input about miscellaneous field information, such as climate data, soil data, and management information

- Growth and fertilizer parameter file. The parameters for most of the major crops have been established by the developers and do not need to be modified.

The climate variables, the soil physical properties, and the management information required by the EPIC model are described below.

EPIC uses a stochastic weather generator to generate daily weather from monthly maximum and minimum temperatures, precipitation, standard deviation of precipitation, skew coefficient for daily precipitation, probability of a wet day after dry day, and probability of wet day after wet day. EPIC can accept up to 20 parameters for 10 soil layers. However, of these at least seven parameters are required: depth, percent sand, percent silt, bulk density, pH, percent organic carbon, and percent calcium carbonate. Other related soil parameters can be estimated by EPIC itself.

EPIC requires detailed descriptions of management practices. These descriptions must specify the timing of individual operations either by date or by fraction of the growth period (that is, by heat units). EPIC allows the user to simulate complex crop rotations by specifying options for irrigation and fertilizer applications in the EPIC program; the applications can be made manually or automatically based on rules.

## Major Crop Growing Seasons

Kharif (June–October) is characterized by a gradual fall in temperature, more numerous cloudy days, low light intensity, a gradual shortening of photoperiod, high relative humidity, and cyclonic weather. During Rabi (November–March), there is a gradual rise in temperature, bright sunshine, near absence of cloudy days, a gradual lengthening of the photoperiod, and lowering of relative humidity.

Rabi weather is more conducive for rice, and, in general, rice yields are higher in Rabi than in Kharif season. However, this does not hold true for maize. Unlike jowar and sunflower, which are mostly Kharif crops, maize can be grown in any climate. Groundnut is raised both in Kharif and Rabi but crop acreage is more in Kharif season. Of the above, validation for five crops could not be done to compare/validate sunflower yield owing to unavailability of reported yield data at the district level.

## Model Testing

Rigorous testing of model performance involves the comparison of reported crop yield to model outputs achieved with conditions similar to

those prevailing for crop growth in the real world. Parameterization is often an iterative process of comparison of the model and observed data and parameter adjustment to achieve a better match. Once the crop model is adjusted, the next step in testing the model is validation against independent data. In this study, observed yields of crops were compared with model outputs for the same crop for the Kharif season. However, because economic data are often gathered in political reporting districts, rather than agro-climatic areas, current results of crop productivity were compared to political districts to ensure that the same can be used as input to economic models.

### **Parameterizing EPIC**

Most of the crop growth parameter sets in EPIC are developed for temperate conditions. They produce high-yield estimates as the potential radiation use efficiency is less in tropical conditions (that is, under Indian conditions). Accordingly, potential radiation use efficiency values (WA; also called biomass-energy ratio) have been lowered from 35 to 10, for groundnut and sunflower to match Indian data. The base temperature (TG) was changed to 8°C from 13.5°C for groundnut (Reddy et al. 2001).

Water stress decreases yield in EPIC by reducing accumulated biomass and the harvest index. Water stress is only allowed to reduce the harvest index over the later portion of the growing season. Harvest index was lowered from 0.40 to 0.30 for groundnut and sunflower to better match field trials in India (ANGRAU 2003). This is consistent with findings that many crops have developmental phases (such as pollination and grain filling) in which water stress is critical. Each of the crop-specific parameters (more than 30 in number) helps compute the growing season water stress through accumulated biomass reduction in the form of mid- and late-season water stress reductions in crop yield (Bryant et al. 1992).

### **Validation**

Validations at the district level were carried out using block-level simulated outputs for the years 1996–8 and annual reported yields for the selected five crops (rice, maize, jowar, groundnut, and sunflower). The validation was done using only Kharif-simulated crop yield for the Kharif season and compared with annual (Kharif + Rabi) reported yields (the only data available). Crops other than rice are often grown in the Rabi season in Andhra Pradesh under drought conditions and with irrigation

supplements. Since the extent of irrigation for particular crops was not known, models of crop yield in the Rabi season could not be expected to match the reported data. Nevertheless, the validation test is still powerful since a predominance of annual yield is derived from the Kharif season. For instance, statistical analysis of the crop-growing region shows that in the Anantapur district of Andhra Pradesh the planted area in the Kharif versus Rabi season were 2.7 times for rice, 3 times for maize, and 41 times for groundnut.

## ANNEX 6

# Planting Area Model

To estimate crop production, both the year-to-year variation in yield and area planted are needed. A statistical model was developed to compute area of each modeled crop (and a category or “other crops”) at the block-level based on the rainfall of that district.

The following data sets were available for building the planting area model:

- District-wise cropped areas for major crops, gross cultivated area (GCA), gross irrigated area (GIA), and cropped areas by source of irrigation were available from 1975–6 to 2002–3
- Cropped areas by season and block are available from 1999–2000 to 2003–4
- Daily, monthly, and annual rainfall for India Meteorological Department stations (1975–2002).

Crop-wise rain-fed areas and gross rain-fed area (GrfA) were calculated as the difference of crop-wise gross areas and irrigated areas.

The planting area model aimed to make use of available data in building the statistical relationship among the variables. Many combinations of variables were tested to answer the following queries. Dependent

variables were rainfall (absolute, lag rainfall, log transformed rainfall, percent change in rainfall) and independent variables were GCA, GIA, and individual cropped areas. One dependent variable was taken at a time to build the model. The model intended to:

- Find any significant relation with previous year's rainfall among areas
- Test any correlation of previous year's monsoon first month rainfall (June) with the planted areas
- Test whether crop areas are related with the monsoon strike date
- Check whether change in areas is related with the change in rainfall

To answer the above, the following combination of variables was used in building the planting area regression models.

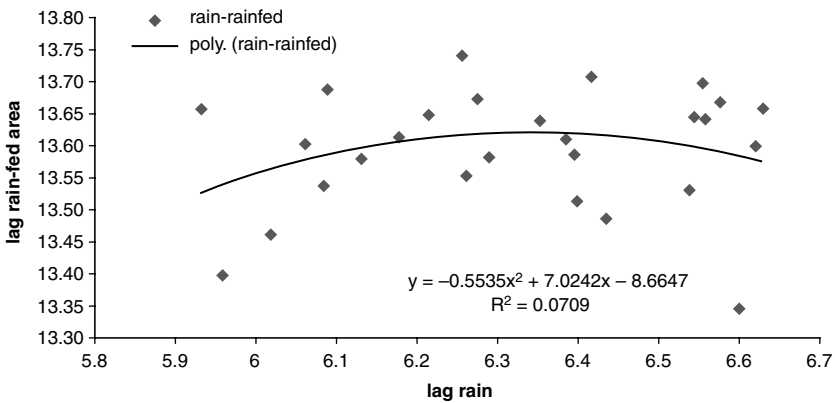
- GCA, GIA, GrfA versus previous year annual rainfall (log transformation)
- GCA, GIA, GrfA versus previous year June rainfall (absolute and log transformation)
- GCA, GIA, GrfA versus current year monsoon strike date
- Change in GCA, GIA, and GrfA over previous year with change in rainfall over previous year

Unfortunately, none of the first three versions gave satisfactory results. There was a lot of scatter and no significant correlation in the first three combinations. The fourth combination gave a good correlation structure among the variables. Hence, it is proposed as a candidate for the planting area model. Results of these plots for Anantapur are shown in figures A6.1–A6.8. Similar patterns have been observed for other districts.

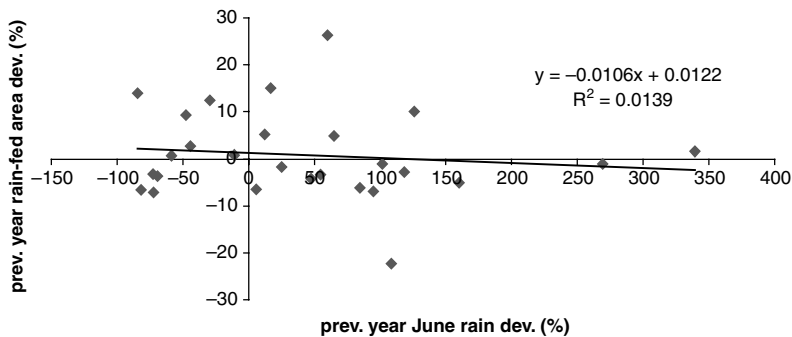
Two linear regression equations, separately for irrigated and GCAs regressed on rainfall, were developed based on district level data from 1975–6 to 2002–3. The GrfA is determined as the difference between GCA and GIA. However, the variables represent their percent changes instead of absolute values. The percent change in rainfall explains the percent change in area better than their absolute values would. Taking any known year/event as the base the equations can give percent changes for the simulated year/event of interest. The percent change in rainfall for each of the stochastic rainfall regression equations are used to calculate the change in GCA and GIA, then absolute areas are calculated with reference to areas in 1998–9.

Distribution factors by crop by season and by block are derived using the 2000–1 and 2003–4 block-level data separately for irrigated and rain-fed areas. The structure of the model is given in figure A6.8. The district cropped area is then disaggregated using the distribution factors. Based on the consistent cropping pattern observed in the four-year block-level data (although limited) an assumption is made that the same pattern would continue in the future.

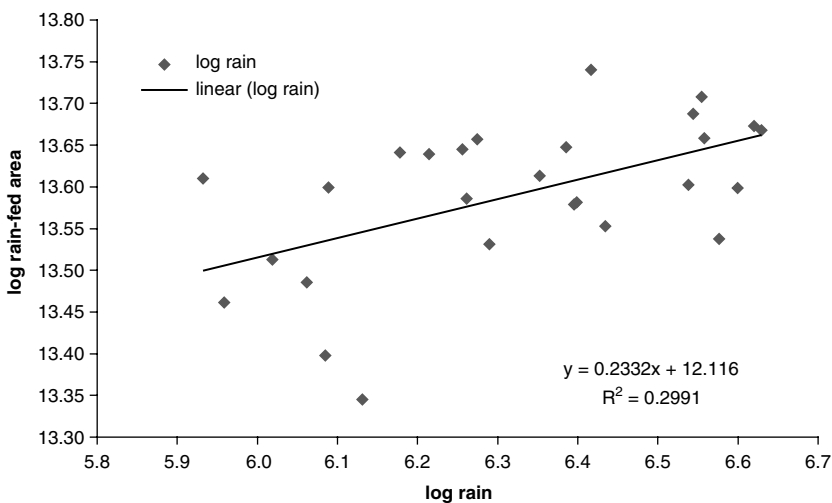
**Figure A6.1. Log of Lag Rain Versus Log of Lag Gross Rain-Fed Areas for Anantapur**



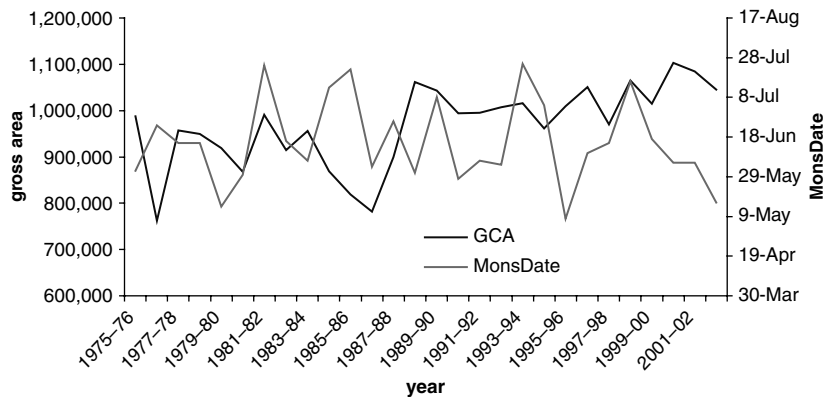
**Figure A6.2. Previous Year June Rain Deviations Versus Current Year Gross Rain-Fed Area Deviation for Anantapur**



**Figure A6.3. Log Transformed Current Year Rain Versus Gross Rain-Fed Area for Anantapur**

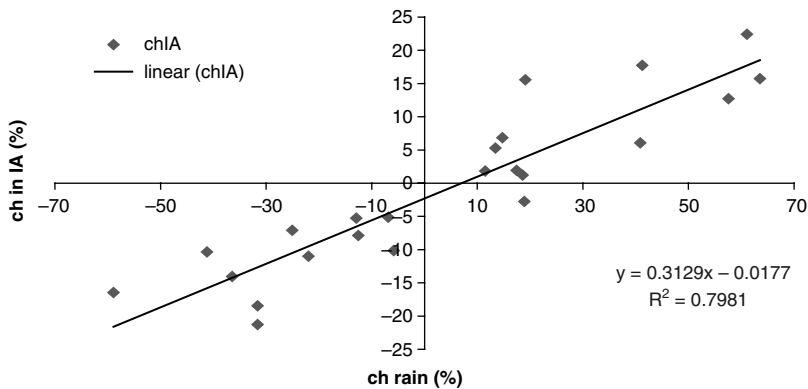


**Figure A6.4. Gross Cropped Area and Monsoon Strike Date Variation Over the Years for Anantapur**

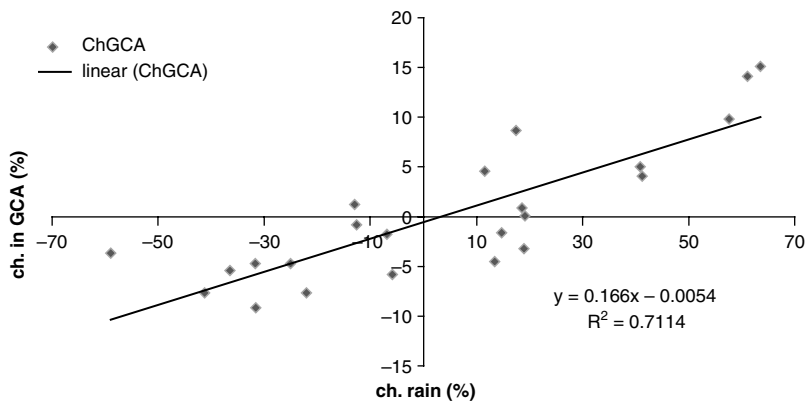




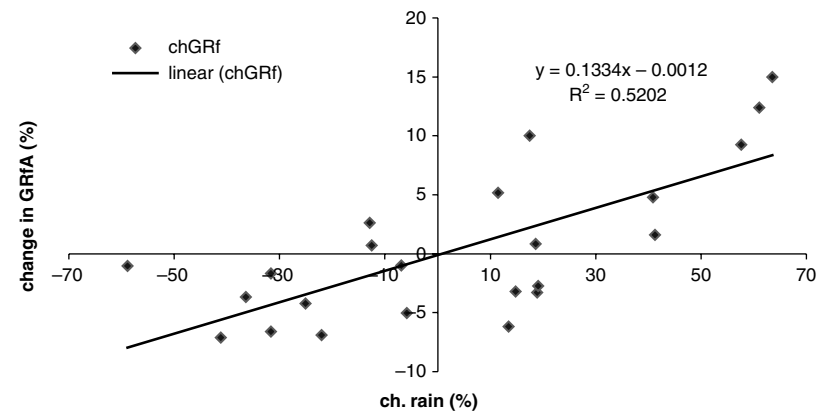
**Figure A6.5. Change in Gross Irrigated Area Versus Change in Annual Rain for Anantapur**



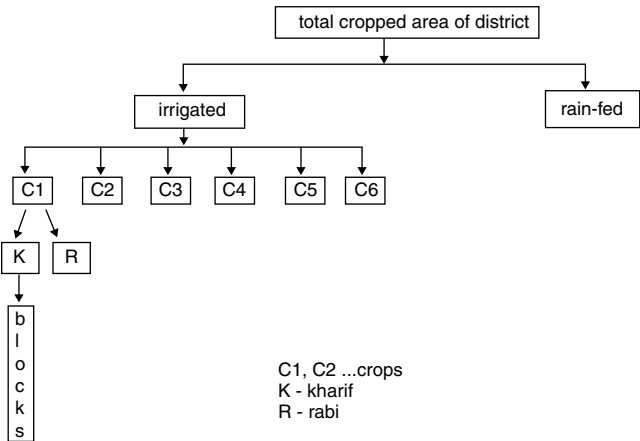
**Figure A6.6. Change in Gross Cropped Area Versus Change in Annual Rain for Anantapur**



**Figure A6.7. Change in Gross Rain-Fed Area Versus Change in Annual Rain for Anantapur**



**Figure A6.8. Structure of the Planting Area Model**



## **ANNEX 7**

# **Input-Output Analysis for Andhra Pradesh**

The Central Statistical Organization has been constructing input-output (I-O) tables in India since 1973–4 at an interval of about five years. The latest (unpublished) table relates to the year 1998–9. The published tables for the years 1989–90 and 1993–4 are for 115 sectors of the economy while for earlier years these relate to 60 sectors only. At the state level, however, I-O tables are not prepared on a regular basis. Some states, such as Punjab, Uttar Pradesh, Assam, and Haryana have prepared tables only once. The table for Andhra Pradesh for the present analysis was constructed for the year 1998–9 using the all-India I-O table along with the available data at state level. This table has been extended for 2000–3. The first section gives details about the sources of data and the methodology. The second section provides the comparative analysis of the constructed I-O tables for the state.

### **Data and Methodology**

The all-India I-O table is available for 1998–9. The I-O table for Andhra Pradesh was prepared in terms of their coefficients for all India, along

with directly available details of crop-wise VOPs for agriculture, the GVA and VOP for livestock, forestry and logging and fishing, mining and quarrying, construction, GVA estimates for registered and unregistered manufacturing (2-digit level), and directly available GVA estimates for various services.

Andhra Pradesh economy has been broadly classified into the following sectors:

- Agriculture
  - Rice
  - Jowar
  - Maize
  - Other food grains
  - Groundnut
  - Other crops
- Livestock
- Forestry and Logging
- Fishing
- Mining and Quarrying
- Manufacturing
  - Food products
  - Textile products
  - Wood products
  - Paper products
  - Leather products
  - Rubber, plastic, coal, and tar and petroleum products
  - Fertilizers
  - Pesticide
  - Chemicals
  - Nonmetallic mineral products
  - Basic metals and alloys
  - Metal products and electrical and nonelectrical machinery and equipment
  - Transport equipment and parts
  - Miscellaneous industry
- Construction
- Services
  - Electricity, gas, and water supply
  - Railway transport services
  - Other sources of transport and storage

- Communication
- Trade hotels and restaurants
- Banking and insurance
- Ownership of dwellings, real estate, and business services
- Education, medical, and other services
- Public administration

### ***Agriculture***

The VOP data for all the crops (1998–9) were obtained from the Directorate of Economics and Statistics, Andhra Pradesh. The values were aggregated to the six sectors mentioned above. Certain adjustments were made in some sectors (such as rice/rice) to take into account the milling, because in the all-India tables, milling is included under agriculture and adjustment was done using the ratios based on the all-India table. The National Accounts Statistics figures for agriculture and from the I-O table (all-India) were considered. The ratio between I-O figures and National Accounts Statistics figures were used for adjustment.

These adjusted figures (VOP data) were used along with all-India coefficients to calculate the Andhra Pradesh input vectors for the six agricultural sectors. Adjustments were made for inputs of fertilizers, electricity, and petroleum products consistent with the estimates provided by the Directorate of Economics and Statistics.

The VOP data for 2002–3 were available for rice, jowar, maize, other food grains, and the total VOP for all the crops from the Directorate of Economics and Statistics.

The VOP of groundnut for 2002–3 was calculated by using the output/production data for 2002–3 and the wholesale price of groundnut for that year. The production figure multiplied with the price data determined the VOP of groundnut for 2002–3. The VOP of other crops is obtained by subtracting the values of output of the first five sectors from the total VOP of all the crops made available by the Directorate of Economics and Statistics. The sector-wise ratio of VOP for 2002–3 over 1998–9 was used over I-O 1998–9 VOP to get the I-O 2002–3 VOP. Thus, the structure of the inputs for the agricultural part of the I-O matrix for Andhra Pradesh for 2002–3 at 1998–9 prices was constructed.

The adjusted GVA and VOP data for the six sectors for 2002–3 were converted to 1998–9 constant prices using the price indices. The total inputs for each of these sectors were calculated by deducting the GVA from the VOP. All the calculations were done on data of 2002–3 at

1998–9 constant prices. These total inputs were distributed to sector-wise inputs by using the Andhra Pradesh 1998–9 coefficients.

### ***Livestock, forestry and logging, fishing, and mining and quarrying***

The GVA and VOP data for the livestock, forestry and logging, fishing, and mining and quarrying sector for Andhra Pradesh were obtained from the Directorate of Economics and Statistics. The difference between the VOP and the GVA provided the inputs to these sectors. The inputs were then distributed using the all-India coefficients. Thus, the input structure for these sectors for Andhra Pradesh for 1998–9 was obtained by using the all-India structure.

The GVA and VOP for livestock, forestry and logging, fishing, and mining and quarrying sectors for 2002–3 were available both at current and constant 1993–4 prices. The GVA and VOP for 2002–3 (at current prices) were converted to 1998–9 constant prices using the price indices. These figures were used to calculate the inputs for each of these sectors, which were distributed using the I-O 1998–9 coefficients. Thus, the input structure for livestock, forestry and logging, fishing, and mining and quarrying sectors for Andhra Pradesh for 2002–3 at constant 1998–9 prices was derived.

### ***Manufacturing sector***

The manufacturing sector at the 2-digit level for all-India as well as for Andhra Pradesh was classified under the previously mentioned heads.

The detailed data of GVA for both registered and unregistered factories were available from the Directorate of Economics and Statistics, Andhra Pradesh, for 1998–9 at current prices at 2-digit level of industrial classification. The Annual Survey of Industries for the registered<sup>1</sup> manufacturing sector provides the GVA and VOP for different sectors of the economy at state level. The unregistered sector estimates of GVA and the VOP were obtained from the survey conducted by the National Sample Survey Organization with reference to 2000–01. It is assumed that the ratio of VOP to GVA for 1998–9 and 2000–1, are the same for the unregistered sector. Using the ratio of VOP to GVA from these sources on the GVA provided by the Directorate of Economics and Statistics, VOPs were obtained separately for registered and unregistered parts of different sectors for 1998–9 and then added. These adjusted figures were used for the calculation of the value of inputs (VOI).

$$\text{VOI} = \text{VOP} - \text{GVA}$$

The VOI for 1998–9 at current prices for the sectors obtained were at the purchaser's prices. The all-India I-O matrix gave the corresponding VOI at the purchaser's prices as well as their sectoral distribution.

The input structure of 1998–9 for the manufacturing sector for Andhra Pradesh was obtained by assuming the all-India input structure for the different sectors. This was done because the detailed data of inputs were not available at state level. This assumed that the structure of inputs for the different sectors is the same for the state and all of India.

The detailed data of GVA for both registered and unregistered factories for all the above sectors were available from the Directorate of Economics and Statistics, Andhra Pradesh, for 2002–3 both at current and constant 1993–4 prices. The GVA data thus obtained was converted to GVA at 1998–9 constant prices. The values of output as well as input structure for different sectors under manufacturing were estimated by using the 1998–99 I-O Andhra Pradesh structure on the 2002–3 GVA at 1998–9 prices. Hence the input structure of the manufacturing sector for the year 2002–3 at constant 1998–9 prices was constructed.

### ***Services***

The GVA data for the services sector for 1998–9 for Andhra Pradesh were obtained from the Directorate of Economics and Statistics, Andhra Pradesh, and data at the all-India level were available from the I-O 1998–9 matrix (all-India). The ratio of Andhra Pradesh to all India was computed and then used to adjust the all-India I-O structure for the services sector. The input structure for the services sector for Andhra Pradesh was thus obtained by using the all-India structure.

The services sector GVA growth rate from 1998–9 to 2002–3 was obtained from the constructed I-O 1998–9 table and the Directorate of Economics and Statistics data were used on the I-O 1998–9 VOP data and the VOP for the year 2002–3 was calculated. The 2002–3 current price VOP data was converted to constant 1998–9 prices using the index. The inputs at 1998–9 constant prices were calculated using the converted GVA and VOP data. These inputs were distributed to different sectors using the 1998–9 I-O coefficients. Hence, the input structure for the services sector of I-O 2002–3 at constant 1998–9 prices was constructed.

### ***Final demand***

The various components of final demand are private consumption expenditure, Government current expenditure, gross fixed capital formation, change in stocks, and exports and imports.

### ***Private final consumption expenditure***

At all-India level the private consumption expenditure is obtained by using the commodity-flows approach. This method cannot be applied at the state level because of the openness of the economy. National Sample Survey conducts quinquennial household surveys on consumption expenditure. Detailed item-wise estimates of consumption expenditure for 1999–2000 are available at state level and also for the country as a whole. There is a vast difference between the all-India estimates obtained from the National Sample Survey and those obtained by the commodity flow approach. For this study, the sector-wise ratios of National Sample Survey expenditure for Andhra Pradesh to that of all-India were applied to the all-India estimates given in the all-India I-O table for the year 1998–9. It is assumed that the degree of difference between National Sample Survey and the commodity flow approach estimates for Andhra Pradesh is the same as for all-India.

The private final consumption expenditure is different from household consumption and includes the expenditure of nonprofit institutions serving households, while the National Sample Survey estimates are only for the households. The estimates based on household survey are different from those given by the I-O table (using the commodity flow approach), and since the estimates in the present study should be consistent with the I-O table, this method was used.

For 2002–3, the per capita expenditure estimates were available separately for rural and urban areas of Andhra Pradesh by broad groups of items available from the National Sample Survey on consumption expenditure. These along with the corresponding population estimates were used to estimate the total expenditure for the same groups of items. Similar estimates for 1998–9 were obtained using the 1998–9 National Sample Survey. From these two sets of estimates the indices of sector-wise growth of expenditure in 2002–3 over 1998–9 was obtained. These indices were applied on the 1998–9 private final consumption expenditure estimates to get similar estimates for 2002–3. It is assumed here that the growth rate under a group remained the same.

### ***Gross fixed capital formation***

Directorate of Economics and Statistics provided the total gross fixed capital formation (GFCF) estimates for 1998–9. GFCF of construction was estimated by subtracting the row total of construction (that is, intermediate use in the form of repair and maintenance) from the VOP.



Capital formation under livestock was obtained by using the ratio of increment in livestock in Andhra Pradesh and increment in all-India livestock to the capital formation in animal husbandry at all-India level.

The estimate of the value of GFCF for rest of the sectors of Andhra Pradesh for 1998–9 was obtained by subtracting the estimates of GFCF in livestock and construction from the total GFCF for Andhra Pradesh. Similar estimates were obtained from the all India table I-O 1998–9. The ratio of these two estimates was used to obtain sector-wise estimates of GFCF for the remaining sectors. Here the assumption was that the distribution of GFCF of machinery sectors is the same for all-India and Andhra Pradesh.

The total GFCF for the year 2002–3 at current prices was made available by the Directorate of Economics and Statistics. The GFCF data for the sectors for 2002–3 was obtained by using the growth index over the 1998–9 GFCF data. The GFCF data obtained at current 2002–3 prices was then converted to constant 1998–9 prices using the sector-wise price indices.

### ***Government final consumption expenditure***

Government final consumption expenditure (GFCE) data for the state for the year 2001–02 to 2003–4 was available from “Economic cum Purpose Classification” of the Andhra Pradesh Government budget 2003–4. The growth rates for the above-mentioned years were used to calculate the GFCE for 1998–9 for the state. The ratio of the state to all-India GFCE for 1998–9 was used on the all-India I-OGFCE sector-wise estimates to get the estimates of GFCE for the state for the year 1998–9.

The total GFCE 2002–3 for the state was available from the above-mentioned source. The growth index of GFCE was used on the 1998–9 sector-wise GFCE figures to get the GFCE for all the sectors for the year 2002–3 at current prices. These figures were then converted to 1998–9 constant prices using the sector-wise price indices.

### ***Imports and Exports***

The imports and exports for the sectors for the years 1998–9 and 2002–3 were obtained by subtracting GFCE, private final consumption expenditure, GFCF, and the intermediate use (row total) from the VOP of each sector. The change in stocks was not considered because of non-availability of data.

### **Employment coefficients**

This provides the number of workers required to produce Rs. 1 lakh VOP. Employment coefficients were used to calculate employment multipliers that will capture the total employment change scenarios.

The employment coefficients for the manufacturing sector of Andhra Pradesh were calculated from employment data for the registered manufacturing sector provided by Annual Survey of Industries and the unregistered sector employment data from National Sample Survey.

The agricultural employment figures available at the state level were used to derive the coefficients for the agricultural sector. It was assumed that the coefficients for all the crops are the same.

Since data for other sectors were not available, estimates based on the all-India employment data available from the Central Statistical Organization and VOPs from the all-India I-O table were used.

### **Multipliers**

This is a quantitative expression of the extent to which some initial, “exogenous” force or change is expected to generate additional effects through interdependencies associated with some assumed and/or empirically established, “endogenous” linkage system.

Two types of multipliers were considered: output and employment. The constructed I-O matrix has been used to calculate the multipliers:

*A*: I-O matrix expressed in terms of their coefficients

*I*: Identity matrix of the same order as *A*.

$$R = (I - A)^{-1}$$

The *R* matrix is of the same order as *A*, and the column total for each of the sectors in the *R* matrix gave the output multipliers for those sectors.

Table A7.1 presents the employment coefficients and output multipliers calculated from the I-O matrix for the year 1998–9. The employment coefficients are quite high for the agricultural sector implying that this sector is the major employment generator for the state. Thus, any external shock to the agricultural sector has a direct impact on the state's employment scenario. The output multiplier for rice/rice showed that one unit (lakh) increase in the final demand of rice/rice results in increase of 1.46 units (lakhs) of gross output in the economy. The output multiplier is highest for metal products and electric and nonelectric

**Table A7.1. Employment Coefficients and Output Multipliers**

<i>Sectors</i>	<i>Employment coefficients</i>	<i>Multipliers</i>	<i>Sectors</i>	<i>Employment coefficients</i>	<i>Multipliers</i>
Rice	5.40	1.45	Pesticides	0.89	2.61
Jowar	5.40	1.43	Chemicals	0.89	1.82
Maize	5.40	1.45	Nonmetallic mineral products	0.95	1.95
Other food grains	5.40	1.52	Basic metals and alloys	0.05	2.54
Groundnut	5.40	1.40	Metal products, electricity and nonelectric machinery and equipment	0.06	2.67
Other crops	5.40	1.22	Transport equipment and parts	0.59	2.10
Livestock	5.40	1.42	Miscellaneous		2.20
Forestry and logging	1.44	1.17	Construction	0.86	1.69
Fishing	0.68	1.25	Electricity, gas, and water supply	0.08	2.20
Mining and quarrying	0.47	1.41	Railway transport services	0.32	2.00
Food products	1.01	2.23	Other transportation and storage	0.62	2.00
Textile products	3.15	2.08	Communication	0.41	1.27
Wood products	9.27	1.61	Trade, hotels, and restaurants	1.29	1.45
Paper products	0.37	2.17	Banking and insurance	0.16	1.36
Leather products	1.14	2.11	Ownership of dwellings, real estate, and business services	0.02	1.12
Rubber, plastic, coal, and tar	0.45	2.12	Education, medical, and other services	1.09	1.79
Fertilizers	0.89	1.09	Public administration	0.92	—

machinery and equipment followed by pesticides. Sectors, such as basic metal and alloys, electricity, gas, and water supply also have very high output multipliers. Overall, the manufacturing sectors have the highest output multipliers.

## Analysis

A comparative study of the two I-O tables reveals that there has been a significant effect of drought on the economy. The effect of the 2002–3 drought can be seen in the production figures of the different sectors.

Table A7.2 presents VOP for all the sectors classified in the I-O table for 1998–9 and for 2002–3 at 1998–9 constant prices. The VOP of the agricultural sector has gone down by as much as 27 percentage points. The output of crops, such as jowar, maize, and other food grains has shown an increase, but the drastic decrease in output of rice and groundnut has outweighed the increase in other crops.

The total VOP of rice relative to the total agricultural output is around 39 percent (1998–9), showing that rice is the major crop grown in Andhra Pradesh. Rice and groundnut are much more water sensitive than the other crops grown in the state. Hence, water scarcity will result in production loss, and the total agricultural sector will be affected by drought. The year 2002–3 was a major drought year, and the VOP of rice and groundnut decreased by 38 percentage points and 57 percentage points (relative to 1998–9), respectively, and thus loss of VOP for the total agricultural sector. The increase in the value of output for the food products, which depends on agricultural sector, was very small.

The shift from rice and groundnut cultivation, particularly rice, to other crops would also result in savings in terms of inputs required for producing these crops. From the I-O table it can be seen that for producing 1 unit of rice/rice 0.23 units of input is required, while for producing 1 unit of jowar and maize 0.16 and 0.20 units of inputs are required. At times of drought, output decreases but the inputs for production remain the same. This can be seen by comparing the input proportions for different sectors under agriculture for 1998–9 and 2002–3. Therefore, any shift in the cropping pattern will result in savings.

The employment situation of a sector gets affected owing to the loss in the production. Employment coefficients provide a measure to account for loss in employment for any loss in production. The agricultural employment coefficient for the state is 5.48. This has been generalized for the agricultural sector as a whole because of the lack of detailed data on

**Table A7.2. Sector-Wise VOP at Current 1998–9 and 2002–3 at Constant 1998–9 Prices**

<i>Sectors</i>	<i>VOP (1998–9)</i>	<i>VOP (2002–3) at constant 1998–9 prices</i>
Rice	1203027	741465
Jowar	35957	41443
Maize	68442	73502
Other food grains	159296	173853
Groundnut	298189	128745
Other crops	1308995	1092593
Livestock	948749	1677690
Forestry and logging	167625	170715
Fishing	351600	583779
Mining and quarrying	341449	560930
Food products	1771993	1979670
Textile products	228304	419022
Wood products	156431	197028
Paper products	294141	214297
Leather products	39573	44068
Rubber, plastic, coal, and tar	321623	1078885
Fertilizers	127262	155265
Pesticides	30351	36456
Chemicals	558991	570962
Nonmetallic mineral products	346845	422691
Basic metals and alloys	1616309	1338809
Metal products, electricity and nonelectric machinery and equipment	520105	620527
Transport equipments and parts	61350	97024
Miscellaneous	52298	152693
Construction	1022581	1524684
Electricity, gas, and water supply	929165	1097889
Railway transport services	313288	369824
Other transport and storage	1093358	1481011
Communication	199006	433838
Trade, hotels, and restaurants	2173966	2553891
Banking and insurance	593644	728509
Ownership of dwellings, real estate, and business services	749610	1000480
Education, medical, and other services	1794171	2577852
Public administration	509668	699591

the crop-wise employment structure for the state. The total employment loss for 2002–03 owing to loss in agricultural VOP is more than 44 lakhs. Encouraging dryland cropping would moderate the effects of drought on the employment scenario.

The livestock sector experienced a 77-percentage point increase in production despite the drought. This suggests that drought had no effect on this sector. The three major components contributing to this sector, milk, meat, and eggs, have behaved differently in the drought years from the normal years. The value of milk as a proportion of the total value of livestock decreased from 55.1 percent to 50.1 percent, while that of meat remained the same (28.5 percent to 27.4 percent). The value of eggs, however, increased from 8.09 percent to 15.23 percent. Thus, it is evident that the poultry sector (not meat) needs to be encouraged. Good performance of this sector during drought may have been due to Government interventions. Livestock feed also decreased over the years and from the I-O table it can be inferred that a substantial decrease in the cost of feed occurred from 1998–9 to 2002–3 (figure 4.1). This may be due to the substantial increase in the share of eggs because of poultry promotion.

The primary sector as a whole has experienced an increase despite the drought, although agricultural sector performance was on the lower side.

Construction showed a 49-percentage point increase in VOP. This may be because Government expenditure in this sector increased owing to poverty alleviation programs, and, hence, employment in this sector went up. The construction output multiplier obtained from I-O was 1.69. Any expenditure in the construction sector will lead to an increase in outputs for sectors, such as cement, steel, bricks, and tiles. Interpreting the multiplier, a 1 unit rise in the output of the construction sector will result in an additional 0.69 units rise in outputs of other sectors because of interlinkages between the sectors. Thus, any investment relating to construction by the Government will boost the increase in output in other sectors. The labor displaced from the agricultural sector may have been absorbed in this sector, moderating the employment loss in the agricultural sector due to drought.

A comparative study of the demand components of the I-O tables revealed that the agriculture sector was the worst affected because of the 2002–3 drought. The production of rice was so low that the state had to import rice. Similarly, for other food grains and crops a decrease in output resulted in imports in these sectors for other states.

## Note

1. The factories that have 10 or more workers and use power or factories that have 20 or more workers and do not use power, are registered (organized) factories. The remaining enterprises are unregistered.

## **ANNEX 8**

# **Structure of the Andhra Pradesh Economy (1980–1 to 2002–3)**

The structure of the Andhra Pradesh economy may be described in terms of changes in the GVA in various sectors of the economy and interrelations between them. The following major sectors were included in the model and analysis:

- Primary sector that includes agriculture, livestock, forestry and logging, fishing and mining and quarrying, of which two subsectors of particular interest—agriculture and livestock—were examined separately for sensitivity to drought.
- Secondary sector that includes manufacturing (both registered and unregistered), electricity, gas and water supply, and construction.
- Tertiary sector that includes trade, hotels and restaurants, railways, transport by other means and storage, communications, banking and insurance, ownership of dwelling, real estate and business, public administration, and other services.

The year 1993–94 was chosen as the benchmark year because the GVA was measured at 1993–4 prices. Fluctuations in GVA during 1980–1 and 1992–3 were compared with those during 1993–4 and 2002–3. The

postulated models were estimated for these subperiods separately, and from 1980–1 to 2002–3, to detect any structural changes.

## **Descriptive Analysis of Changes in the GVA of Major Sectors**

### ***Primary sector***

Agriculture and livestock were clubbed together because separate data on agriculture and livestock GVA were not available for the earlier subperiod 1980–1 to 1992–3.

***Changes in the GVA of agriculture and livestock.*** The years 1984–5 and 1986–7 showed low productivity in agriculture and livestock. The annual percentage change and the combined GVAs were –8.7 and –10.8, respectively. These years may be classified as years of severe drought. Years 1990–1 and 1992–3 had mild drought conditions, as the annual percentage change in GVA of agriculture and livestock were –2.9 and –1.1, respectively.

During the subperiod 1993–4 to 2002–3 we observed highly negative annual percentage change in the GVA of agriculture and livestock during the years 1997–8 and 2002–3. These were –18.8 in 1997–8 and –12.5 in 2002–3. Thus, 1997–8 and 2002–3 were years of severe drought. However, 1999–2000 also showed a highly negative (–4.02) percentage change in the GVA of agriculture and livestock. Thus, 1999–2000 should also be treated as the year of severe drought even though it was of relatively lower intensity than that of 1997–8 and 2002–3. The other years showing negative annual percentage change in agriculture and livestock were 1994–95 (with –2.14) and 2001–02 (with –0.95).

The share of agriculture and livestock in the primary sector GVA has consistently decreased over the entire period 1980–1 to 2002–3. It was as high as 88 percent in 1982–3 and 1983–4 and decreased to 85 percent in 1992–3 and further decreased over the second subperiod (1993–4 to 2002–3). It remained in the range of 80–84 percent during 1993–4 and 2001–2 and was 75.52 percent in 2002–3.

***Changes in the GVA of components other than agriculture and livestock in the primary sector.*** Mining and quarrying, and fishing have consistently improved their share in the primary sector GVA. During 1980–1 and 1992–3 the share of mining and quarrying was 3–6 percent, and it increased to 7–9 percent during 1993–4 and 2001–2. It was 11.3 percent



in 2002–3. Similarly, the share of fishing was 4–6 percent from 1980–1 to 1992–3, and increased to 5–8 percent from 1993–4 to 2001–2. It stood at 10.32 percent in 2002–3.

Forestry and logging share in the primary sector GVA (PGVA) was 3–5 percent over the entire period 1980–1 to 2002–3.

Thus, it appears that while agriculture, livestock, and forestry were worst affected by drought, sectors such as mining and quarrying and fishing improved. Mining and quarrying recorded a 12-percentage point and fishing 19.6-percentage point change annually in their GVA in 2002–3.

### ***Secondary sector***

The share of manufacturing in the secondary sector GVA was 55–64 percent during 1980–1 and 1992–3 and 62–67 percent in 1993–4 and 2002–3. A decrease in the percentage share of manufacturing was observed from 1999–2000 to 2002–3: 62 percent and 63 percent during this period compared to more than 66 percent in 1993–4 and 1998–9. This may be attributed to drought conditions during 1997–8 and 2002–3 because the raw material for manufacturing comes from agriculture.

The share of construction in the secondary sector GVA decreased consistently from 36 to 21 percent from 1980–1 to 1996–7 but started to increase slowly from 1997–8 to 2002–3 (22–26 percent). This could be due to the result of efforts made to mitigate hardships caused by drought conditions.

### ***Tertiary sector***

The percentage share in GVA of communications, banking and insurance consistently increased from 1980–1 to 2002–3. Although the share of communications was small (ranging from 2.28 in 1980–1 to 7.08 in 2002–3), it almost trebled over the years and that of banking and insurance doubled. The subsectors of trade, hotels and restaurants, and transport and storage maintained almost the same percentage share over the years. Surprisingly, the share of railways has decreased from about 5 percent (1980–1 to 1987–8) to less than 4 percent (1993–4 to 2002–3).

## **Specification of the Macro Model in Terms of Sector-Wise GVA**

Specification of a macro model requires postulating structural equations, which describe changes that directly influence GVA in terms of certain

variables. These variables need to be identified and their relationship to GVA in each of the sectors determined.

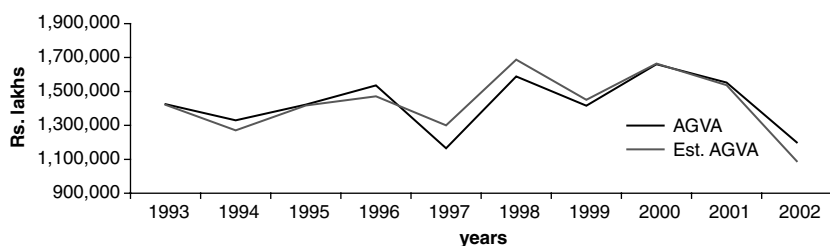
In the present study, the model was postulated in the form of a set of interdependent regressions, in log linear form, the parameters were estimated by the SUR method. The estimated coefficients may be interpreted as partial elasticity coefficients.

The GVA was calculated as the difference between the values of output and inputs (at current or constant prices). However, the inputs did not include the consumption of fixed capital.<sup>1</sup> For example, in agricultural GVA the inputs are seed, chemical fertilizers, organic manure, current repairs and maintenance of fixed assets, market charges, irrigation charges, electricity, pesticides and insecticides, and diesel. Therefore, the specification of structural equations for GVA, in each of the sectors, should include consumption of fixed capital as one of the explanatory variables.

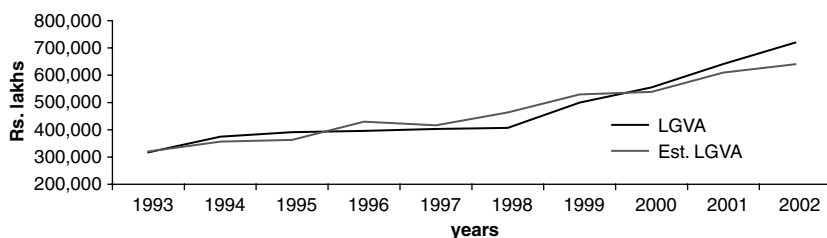
### Macro Model for the Major Components of Different Sectors of the Andhra Pradesh Economy

Agriculture is the major constituent of the primary sector and manufacturing that of the secondary sector. Agriculture and livestock were worst affected during drought years. Ideally, a model that accounted for agriculture and livestock separately during both the subperiods (1980–1 to 1992–3 and 1993–4 to 2002–3) should have been postulated and performance of the model compared over the subperiods. Unfortunately, data on GVA from agriculture and livestock were aggregated for 1980–1 to 1992–3 and were not available separately for agriculture and livestock. However, agriculture GVA and livestock GVA were separately available for 1993–4 to 2002–3. See figures A8.1–A8.4.

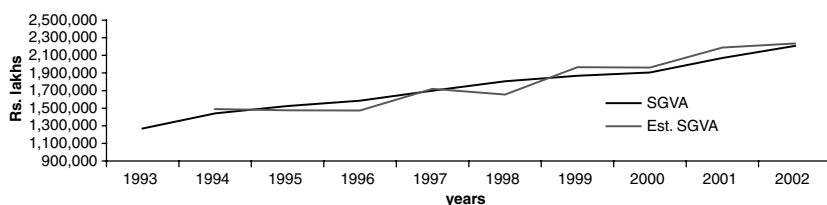
**Figure A8.1. Agriculture GVA, 1993–94 to 2002–03, Estimated and Observed**



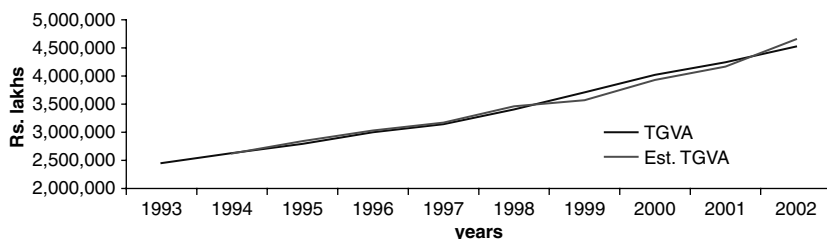
**Figure A8.2. Livestock GVA, 1993–94 to 2002–03, Estimated and Observed**



**Figure A8.3. Secondary Sector GVA, 1993–94 to 2002–03, Estimated and Observed**



**Figure A8.4. Tertiary Sector GVA, 1993–94 to 2002–03, Estimated and Observed**



The estimated model for 1993–4 to 2002–3 is given below.

$$\begin{aligned} \ln(\text{AGVA}) &= 1.03 \ln(\text{ACFC}) + 0.25 \ln(\text{VOP}_{4,8}); \quad \bar{R}^2 = 0.73 \\ (10.53) \qquad \qquad \qquad (2.98) \end{aligned}$$

$$\ell_n \text{ (LGVA)} = 0.98 \ell_n \text{ (LCFC)} + 0.24 \ell_n \text{ (AGVA)}; \bar{R}^2 = 0.90$$

(14.64)
(5.32)

$$\ell_n(\text{SGVA}) = 0.72 \ell_n(\text{SCFC}) + 0.37 \ell_n(\text{AGVA}_{-1}); \bar{R}^2 = 0.84$$

(8.77)
(4.94)

$$\ln(\text{TGVA}) = 1.33 \ln(\text{TCFC}) - 0.12 \ln(\text{AGVA}_{-1}); \bar{R}^2 = 0.98$$

(26.05)                      (-2.70)

[From the  $t$ -distribution on 8 d.f.  $P(|t| > 1.86) = .05$ ]

In the above equations:

AGVA = agricultural GVA

LGVA = livestock GVA

SGVA = secondary GVA

TGVA = tertiary sector GVA

ACFC = consumption of fixed capital in agriculture

LCFC = consumption of fixed capital in livestock

SCFC = consumption of fixed capital in secondary

TCFC = consumption of fixed capital in tertiary sector

VOP<sub>4,8</sub> = value of output for four crops eight districts

AGVA<sub>-1</sub> = last year's agricultural GVA

The key data series exhibited strong trends and were nonstationary, which may lead to the familiar problem of "false inference." To identify the appropriate cointegrating relationships a number of detrended regressions were conducted. Among these, the following is a representative example. It involves a regression for the period 1981–2002, which yielded the following model:

$$\ln(dAGVA) = 4732 + 5.31 \ln(dACFC) + 0.14^* \ln(dVOP_{4,8}); \bar{R}^2 = 0.32$$

$$\ln(dSGVA) = 40700^* + 1.76^* \ln(dSCFC) + 0.04 \ln(dAGVA_{-1}); \bar{R}^2 = 0.44$$

$$\ln(dTGVA) = 110260^* + 5.28^* \ln(dTCFC) - 0.05 \ln(dAGVA_{-1}); \bar{R}^2 = 0.36$$

where \* is statistically significant at 5 percent confidence level.

In the above equations:

dAGVA = AGVA – AGVA<sub>-1</sub>

dSGVA = SGVA – SGVA<sub>-1</sub>

dTGVA = TGVA – TGVA<sub>-1</sub>

dACFC = ACFC – ACFC<sub>-1</sub>

dSCFC = SCFC – SCFC<sub>-1</sub>

dTCFC = TCFC – TCFC<sub>-1</sub>

dVOP<sub>4,8</sub> = VOP<sub>4,8</sub> – (VOP<sub>4,8</sub>)<sub>-1</sub>

In this model, an increase in AGVA in the previous year would create a positive impact on the secondary sector and a negative impact on the tertiary sector, as found under the previous model. However, these coefficients were not statistically significant at 5 percent confidence level. The

small size of the sample diluted the statistical power of the usual battery of specifications and model selection tests. Hence, it was not possible to statistically identify the most appropriate model. Under the circumstances, trended specification was opted for because of its superior predictive power. However, because of the statistical limitations of a restricted sample size, the choice should be viewed as tentative. Estimates obtained from most of the alternative specifications were within 3 standard errors of the chosen model. Hence, the coefficients of the chosen model were best viewed as indicative of sectoral linkages, rather than as precise estimates.

**Note**

1. The net value added is defined as the difference between the GVA and consumption of fixed capital.



# Glossary

**Annual rate of occurrence** The average number of occurrences per year. Not to be confused with the term “probability,” which refers to the probability of at least one event occurring in a year.

**Base year** The starting year for financial calculations; that is, a benchmark with which future years are compared or calculated against.

**Block/mandal** An administrative subdivision of the district, which in turn is a subdivision of the state.

**Crop simulation** This can predict yield with a priori knowledge of the soil properties and management practices. The model simulated plant development and growth and soil processes to estimate yield.

**Crop yield** The measurable produce of economic value from a crop. This may be evaluated in terms of quantity and/or quality. Yields are stated as kg/ha or t/ha.

**Crore** 1 crore = 10,000,000.

**Deterministic model** A model that assesses the impact of a hazard by investigating the severity of a single possible outcome.

**District domestic product or district income** The sum of the economic value of goods and services produced within the geographical boundaries of the district irrespective of the income and owned by persons living inside or outside the district. Thus, the estimates of domestic product at the district level are compiled by following the income originating approach as done for gross state domestic product

estimates. Because of the open character of the economic activities and absence of data relating to inter district flows, the income accruing concept is not followed as in the case of state domestic product. District per capita income estimates, when studied in relation to the total population of the district, indicate the level of per capita net output of goods and services available or the standard of living of the people in the district.

**Drought** Drought is defined in many ways, such as a period of dry weather, a condition when precipitation is insufficient to meet established human needs, comparison of normal precipitation months and years, a prolonged dry weather causing hydrologic imbalance, a time-space duration distribution of percent of normal precipitation, and so on.

**Drought index** Several indices are being used to estimate drought severity, including (a) the variable to be used (for example, rainfall, runoff aquifer level, Palmer Drought Index); (b) duration considered (for example, annual, seasonal, instantaneous minimum); (c) truncation level (for example, percentage, quantile, standardized anomaly); and (d) area or region (for example, single site, river basin, country zone).

**Economic loss** The total monetary cost incurred, whether insured or not, because of a shock.

**Environment Policy Integrated Climate model** A computer model of crop growth and soil loss used to understand the impact of management actions and climate on agricultural productivity. The first versions of the model were referred to as the Erosion Productivity Impact Calculator but it has now been renamed as the Environment Policy Integrated Climate model to reflect its wider scope.

**Evaporation** A process by which a liquid or a solid (sublimation) enters the gas phase. In the hydrologic context, it refers to the conversion of water and ice at the earth's surface to water vapor and its dissipation into the atmosphere.

**Evapotranspiration** The combined effect of evaporation and transpiration.

**Event loss table** In its basic form contains columns of event identification, event loss, and event rate of occurrence. In its expanded form the columns for associated uncertainties of loss and rate are also provided.

**Event set** A set of discrete events used in probabilistic risk modeling to simulate a range of possible outcomes.

**Exceedance probability** See "exceeding probability."

**Exceeding probability** Also known as "exceedance probability." The probability of exceeding specified loss thresholds. In risk analysis, this



probability relationship is commonly represented as a curve (the EP curve), which defines the probability of various levels of potential loss for a defined structure or portfolio of assets at risk of loss from natural hazards.

**Exposure** The total value or replacement cost of assets (such as structures) that are at risk from a loss-causing event such as a catastrophe.

**Final consumption expenditure** The spending on goods and services used for the direct satisfaction of individual or collective needs, as distinct from purchases for use in a productive process.

**Fixed capital** Long-term capital used for long-term investments in fixed assets (for example, land, buildings, equipment, machines).

**Gross cropped area** The total area under all crops.

**Gross fixed capital formation** The investment in assets that are used repeatedly or continuously over a number of years to produce goods. For example, machinery used to create a product.

**Gross irrigated area** The total irrigated area under various crops during a year, counting the area irrigated under more than one crop during the same year as many times as the number of crops grown and irrigated.

**Gross state domestic product** A measure of economic activity in a state. Calculated by adding the total value of the state annual output of goods and services.

**Gross value added** The difference between output and intermediate consumption for any given sector/industry. That is, the difference between the value of goods and services produced and the cost of raw materials and other inputs, which are used up in production.

**Harvest index** A crop parameter-based experimental data where crop stresses have been minimized to allow the crop to attain its potential. The EPIC model adjusts the index as water stress occurs close to flowering time.

**Hazard** A condition that may create or increase the chance of loss from a peril.

**Indirect taxes** Taxes that do not come straight out of a person's pay packet or assets or out of company profit (for example, consumption tax such as value-added tax).

**Intensity** A measure of the physical strength of a damage-causing event, such as a drought. Common scales for intensity include Standard Precipitation Index or Palmer Drought Severity Index for drought.

**Intermediate consumption** The cost of raw materials and other inputs that are used up in the production process.

**Inventories** Formerly called stocks. Consist of materials and supplies stored for use in production, work in progress, finished goods, and goods for resale.

**Irrigation** A method of purposely providing land with water, other than rain water, by artificial means.

**Kharif season** Characterized by a gradual fall in temperature, more numerous cloudy days, low light intensity, a gradual shortening of photoperiod, high relative humidity and cyclonic weather. The kharif season depends entirely on the southwest monsoon receiving more than 70 percent of the annual aggregate rainfall during monsoon months of June–September.

**Lakh** 1 lakh = 100,000.

**Macroeconomic model** Studies the overall aspects and workings of an economy, such as income, output, and the interrelationship among the diverse economic sectors.

**Mitigation** A process by which adverse environmental impacts of an activity are minimized or replaced by beneficial features.

**Net area irrigated** The total of all the areas irrigated from different sources, counting each area irrigated only once even though it was irrigated more than once in the same year.

**Net area sown** The area sown with crops and orchards, counting the area sown more than once in the same year.

**Northeast monsoon** The rainy season that affects southern India from October to December.

**Peril** Includes storms (hurricane, tornado, other windstorm), earthquakes, floods, or drought.

**Price** The value of the goods or money that must be given up to acquire goods or services.

**Price indices** The statistical measure of average changes over time in the prices of commodities relative to a base year.

**Probabilistic model** A model that assesses the impact of a hazard and assigns probabilities to a whole range of possible outcomes.

**Probability** See “annual rate of occurrence.”

**Probability of exceeding** The probability that the actual loss level will exceed a particular threshold.

**Probability of nonexceeding** The probability that the actual loss level will not exceed a particular threshold.

**Probable maximum loss** A general concept applied in the insurance industry for defining high loss scenarios that should be considered when underwriting insurance risk. The exact probability or return period associated with a probable maximum loss can vary based on the company's policies and objectives.

**Rabi season** In Rabi, a gradual increase in temperature, bright sunshine, near absence of cloudy days, a gradual lightening of the photoperiod, and a lower relative humidity. During Rabi season, rainfall occurs from October to December.

**Radiation-use efficiency** This is the potential (unstressed) growth rate (including roots) per unit of intercepted photosynthetically active radiation.

**Regression** Regression analysis is the study of the dependence of one variable (the dependent variable) on one or more other variables (the explanatory variables), with a goal of estimating and/or predicting the mean or average value of the former in terms of the known or fixed values of the latter.

**Return period** The expected length of time between recurrences of two events with similar characteristics. Can refer to hazard events such as hurricanes or earthquakes, or it can refer to specific levels of loss (for example, a US\$100 million loss in this territory has a return period of 50 years).

**Risk** A measure of potential financial loss, commonly encompassing two factors: exposure or elements at risk (amount of value subjected to potential hazard), and specific risk (the expected degree of loss owing to a particular natural phenomenon). This is also used more generally in insurance markets to refer to a specific property covered by an insurance or reinsurance policy.

**Risk management** The management of the varied risks to which a business firm or corporation might be subject. It involves analyzing all exposures to gauge the likelihood of loss and determining how to minimize losses by such means as insurance, self-insurance, reduction, or elimination of risk or the practice of safety and security measures.

**Runoff** Refers to agricultural runoff and occurs when the precipitation rate exceeds the infiltration rate of the soil.

**Site** Same as location; defines exposure data. A site may represent multiple buildings in proximity that are of similar construction and have a single deductible amount.

**Southwest monsoon** The main rainy season in India that occurs from June to September.

**Stochastic drought** A possible drought scenario created as part of a probabilistic model, whose probability has been assigned using probability distributions from the historical record.

**Transpiration** The process by which water vapor escapes from living plants and enters the atmosphere. Includes water that has transpired through leaf stomata, as well as intercepted water that has re-evaporated. When a growing crop covers the soil, transpiration greatly exceeds evaporation.

***t*-statistic** After an estimation of a coefficient, the *t*-statistic for that coefficient is the ratio of the coefficient to its standard error. That can be tested against a *t* distribution to determine how probable it is that the true value of the coefficient is really zero.

**Validation** The process by which probabilistic models and assumptions are reviewed and compared to empirical data (such as historically observed losses or insurance claims) to confirm that the model approach and assumptions generate reasonable estimates of potential loss.

**Value of production output** Measures the total value of goods and services produced by a sector.

**Vulnerability** The degree of loss to a system or structure resulting from exposure to a hazard of a given severity.

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Drought sets off a vicious cycle of socio-economic impacts that leave the poor more vulnerable to another drought and other shocks. *Overcoming Drought* applies recent advances in modeling climate-related risks and adjusts state-of-the-art catastrophic risk modeling techniques to drought. The result is an innovative long-term assessment of how to reduce the impacts of drought under several economic, drought management, and climate change scenarios. This assessment helps in identifying and recommending adaptation strategies at local and state levels.

The analysis focuses on the most drought-prone districts of the state of Andhra Pradesh in India and measures the impacts of drought-related losses in these districts on state-wide indicators of economic performance. Although long-term macroeconomic effects of drought appear modest, the human and social costs remain devastating for the millions of people in the poorest rain-fed areas of Andhra Pradesh. An effective response to drought must account for a large variation in impacts from village to village. *Overcoming Drought* highlights the need and directions for intensifying efforts to deliver better packaged knowledge-based assistance to the affected communities, so as to enable a sustainable drought adaptation process.

*Overcoming Drought* will be of great interest to readers working in microfinance, agriculture, rural development, natural resource management, and climate change. The study also has significant implications for agricultural and climate-related insurance.



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