Drought in Andhra Pradesh:
Long term impacts and adaptation strategies

Final Report

Volume 1: Main Report

South Asia Environment and Social Development
Department
World Bank
September 2005

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ACKNOWLEDGEMENTS

The study team would like to acknowledge and sincerely thank the Government of Andhra Pradesh (GoAP), officials from Government of India's Department of Agriculture, Confederation of Indian Farmers Association, and various organizations and researchers who have guided the direction of this study at different stages and contributed in a substantive way towards its successful completion.

We would like to express special gratitude Dr. Mohan Kanda, Chief Secretary, Government of Andhra Pradesh (GoAP) for supporting this study, Mr. Tishya Chatterjee, IAS, Principal Secretary, Environment Forests Science and Technology Department for his strong leadership and coordination with other departments , Dr. S.N. Jadhav, Additional Secretary and Chief Vigilance Officer, Environment, Forests, Science and Technology Department, and Mr. W.G. Prasanna Kumar, Director, National Green Corps, AP.

We would also like to thank Mr. Shashank Goel, Commissioner, Disaster Management Department and Asutosh Mishra, former Commissioner, for excellent cooperation and guidance on the study; Mr. A.K. Goel, IAS, Principal Secretary, Planning Department for valuable insights on the impact of drought on the socio-economic situation of the people in rain-shadow areas and Mr. A. K. Parida, former Secretary of Planning, for sharing the work commenced by the planning Department on the developing real-time decision support system for drought management

We would like to acknowledge cooperation and help extended to the mission by officials from several other GoAP departments and agencies, including the Water Conservation Mission of the Rural Development Department, and Departments of Agriculture, Rains-Shadow Area Development, Irrigation and Groundwater Management.

We would like to recognize the insights and comments provided by experts from research organizations in Andhra Pradesh, particularly, ICRISAT, CRIDA, Agriculture University, ASCI and NIRD, who participated in several consultation meetings.

Finally, we are very thankful to all participants of the inception and intern review meetings held in Hyderabad in October 2004 and February 2005, respectively, and a stakeholder consultation workshop to discuss the draft final report that took place in Hyderabad on July 19, 2005. gratefully acknowledged.

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The team appreciates support and guidance by Jeffrey S. Racki, Sector Director, South Asia Environment and Social Development Department; Michael Carter, Country Director for India, Fayez Omar, Senior Country Manager for India, and Rachid Benmessaoud, Operations Advisor for India. Financial assistance by the Government of Norway through the Trust Fund for Environmentally and Socially Sustainable Development is gratefully acknowledged.

GLOSSARY

Annual rate of occurrence
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 year, which is taken as the starting year for financial calculations, i.e. a benchmark with which future years are compared or calculated against.

Block/*Mandal*
An administrative sub-division of district which in turn is a sub-division of state.

Crop simulation
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 in units such 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 (DDP) or District Income
Is the sum of the economic value of goods and services produced within the geographical boundaries of the district irrespective of the income is 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 is followed in case of GSDP estimates. In view of the open character of the economic activities and absence of data relating to inter district flows "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 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”, etc.

Drought index
Several indices are being used in estimating the drought initiation and severity. A succinct list of necessary ingredients of any definition: (i) the variable to be used, e.g. rainfall, runoff aquifer

level, Palmer Drought Index; (ii) duration considered, e.g. annual, seasonal, instantaneous minimum; (iii) truncation level, e.g. percentage, quantile, standardized anomaly, and; (iv) area or region, e.g. single site, river basin, country zone.

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

Evaporation
It is the 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
Evapotranspiration refers to the combined effect of evaporation and transpiration.

Event loss table (ELT)
In its basic form an event loss table contains columns of event ID, event loss and event rate of occurrence. In its expanded form columns for associated uncertainties of loss and rate are also provided.

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

Exceedance probability (EP)
See "**exceeding** probability".

Exceeding probability
Also known as "**exceedance** probability" or "EP", it is 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 is at risk from a loss-causing event such as a catastrophe.

Final consumption expenditure
Spending on goods and services that are 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 (ex. land, buildings, equipments, machines etc)

Gross cropped area
Total area under all crops is known as Gross Cropped Area

Gross fixed capital formation (GFCF)
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 (GSDP)
GSDP is a measure of economic activity in a state. It is calculated by adding the total value of the state annual output of goods and services.

Gross value added (GVA)
Value Added is 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 (HI)
This is a crop parameter based experimental data where crop stresses have been minimized to allow the crop to attain its potential. EPIC adjusts HI as water stress occurs near flowering.

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, a consumption tax such as Value-Added Tax).

Intensity
A measure of the physical strength of a damage causing event such as an earthquake or a drought. Common scales for intensity include the MMI scale for earthquakes and the SPI or PDSI, etc. for drought.

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

Inventories
Formerly called stocks, these consist of materials and supplies which are stored for use in production, work-in progress, finished goods and goods for re-sale.

Irrigation
A device of purposely providing land with water other than rain water by artificial means.

Kharif season
Kharif 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. The *kharif* season depends entirely on the southwest monsoon receiving over 70% of the annual aggregate rainfall during monsoon months of June to September.

Lakh
1 Lakh = 100,000

Macro model
The model that studies the overall aspects and workings of an economy, such as income, output, and the interrelationship among the diverse economic sectors.

Mitigation
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
Area sown with crops and orchards, counting the area sown more than once in the same year, only once.

Northeast monsoon
Rainy season that affect only the southern Peninsular India extending from October to December.

Peril
The loss producing agent, such as a storm (hurricane, tornado, other windstorm), earthquake, flood or drought.

Price
The value of the goods or money that must be given up to acquire a good or service.

Price indices
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 non-exceeding
The probability that the actual loss level will not exceed a particular threshold.

Probable maximum loss (PML)
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 PML can vary based on the company's policies and objectives.

Rabi season
In Rabi, there is a gradual rise in temperature, bright sunshine, near absence of cloudy days, a gradual lightening of the photoperiod and a lower relative humidity. Rainfall is received in Rabi season during 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. The return period can refer to hazard events such as hurricanes or earthquakes, or it can refer to specific levels of loss (e.g. a USD $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 due to a particular natural phenomenon). Also used more generally in insurance markets to refer to a specific property covered by an insurance or reinsurance policy.

Risk management
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
In this study runoff refers to agricultural runoff and it occurs when the precipitation rate exceeds the infiltration rate of the soil.

Site
Same as location. When defining exposure data, a site may represent multiple buildings in close proximity that are of similar construction, and have a single deductible amount

Southwest monsoon
The main rainy season in India which extends 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
It is the process by which water vapor escapes from living plants and enters the atmosphere. It includes water, which has transpired through leaf stomata, as well as intercepted water, which 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
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 output
This measures the total value of goods and services produced by a sector.

Vulnerability
Degree of loss to a system or structure resulting from exposure to a hazard of a given severity.

ABBREVIATIONS

AAL	Average Annual Loss
ACFC	Agricultural Consumption of Fixed Capital
AGVA	Agricultural Sector Gross Value Added
ANGRAU	Acharya NG Ranga Agricultural University
AP	Andhra Pradesh
APEP	Andhra Pradesh Environment Program
APNGCS	Andhra Pradesh National Green Corps
ARS	Agricultural Research Service
CAD	Command Area Development
CCS	Climate Change Scenario
CRF	Calamity Relief Fund
CRIDA	Central Research Institute for Dryland Agriculture
DAS	Days after sowing
DES	Directorate of Economics and Statistics
DPAP	Drought Prone Area Program
DPIP	Andhra Pradesh District Poverty Initiatives Project
DSSAT	Decision Support Tool for Agro-technology Transfer
EPC	Exceedance Probability Curve
EPIC	Erosion Productivity Impact Calculator
ERS	Economic Research Service
GCM	Global Climate Models
GDP	Gross Domestic Product
GoAP	Government of Andhra Pradesh
GOI	Government of India
GSDP	Gross State Domestic Product
GVA	Gross Value Added
Ha	Hectare
HADRM2	Hadley Regional Model 2
IAS	Indian Administrative Service
ICASA	International Consortium for Agricultural Systems Applications
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
IO	Input Output
IPCC	Intergovernmental Panel on Climate Change
LCFC	Livestock Consumption of Fixed Capital
LEC	Loss Exceedance Curve
LGVA	Livestock Sector Gross Value Added
MCM	Million Cubic Meters
MDR	Mean damage ratio
MT	Metric Ton
NCCF	National Calamity Contingency Fund
PML	Probable Maximum Loss
RCM	Regional Climate Models
SCFC	Secondary Sector Consumption of Fixed Capital
SCS	Soil Conservation Service
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
USD	United States Dollar
VOP	Value of Production ouput
WALTA	Andhra Pradesh Water Land and Trees Act 2002
WXGEN	Weather Generator

EXECUTIVE SUMMARY

1. Drought sets off a vicious cycle of socio-economic 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; 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 1950s, as evident through programs such as the Drought Prone Areas Programme, Desert Development Programme, National Watershed Manegement Porgrammer for Rainfed Areas, National Calamity Contingency Fund, and the National Agricultural Crop Insurance Scheme. However, the human and social costs of droughts remain devastating.

2. Andhra Pradesh (AP) is one of the states in India which has historically been most severely affected by drought. The failure of monsoons has had a disastrous affect on the states' sizable agriculture sector and a large share of the population dependent on agriculture for livelihood. This study focuses on the eight (out of total 23) districts in AP, which are particularly vulnerable to drought: Anantapur, Chittoor, Cuddapah and Kurnool in Rayalaseema region; Rangareddi, Mahbubnagar and Nalgonda in Teleangana region; and Prakasam in coastal Andhra.

3. Together, these districts are home to about 30 million people and account for about 70% of stat-wide crop production loss due to drought. They also include some of the poorest areas and communities in the state. The Government of Andhra Pradesh (GoAP) attaches high priority to uplifting these areas, as demonstrated by the creation of a dedicated Department for Rain-Shadow Areas Development. While the government continues to explore possibilities to increase areas under the surface water command and/or further develop groundwater resources, there are serious technical and economic constraints to increasing the volume of irrigation water for much of the area within these districts. Thus, there is a wide recognition in AP of the need to complement those efforts with an *adaptation process* of gradual shift to agricultural and other economic practices that are more sustainable under this resource constraint.

Study Objectives

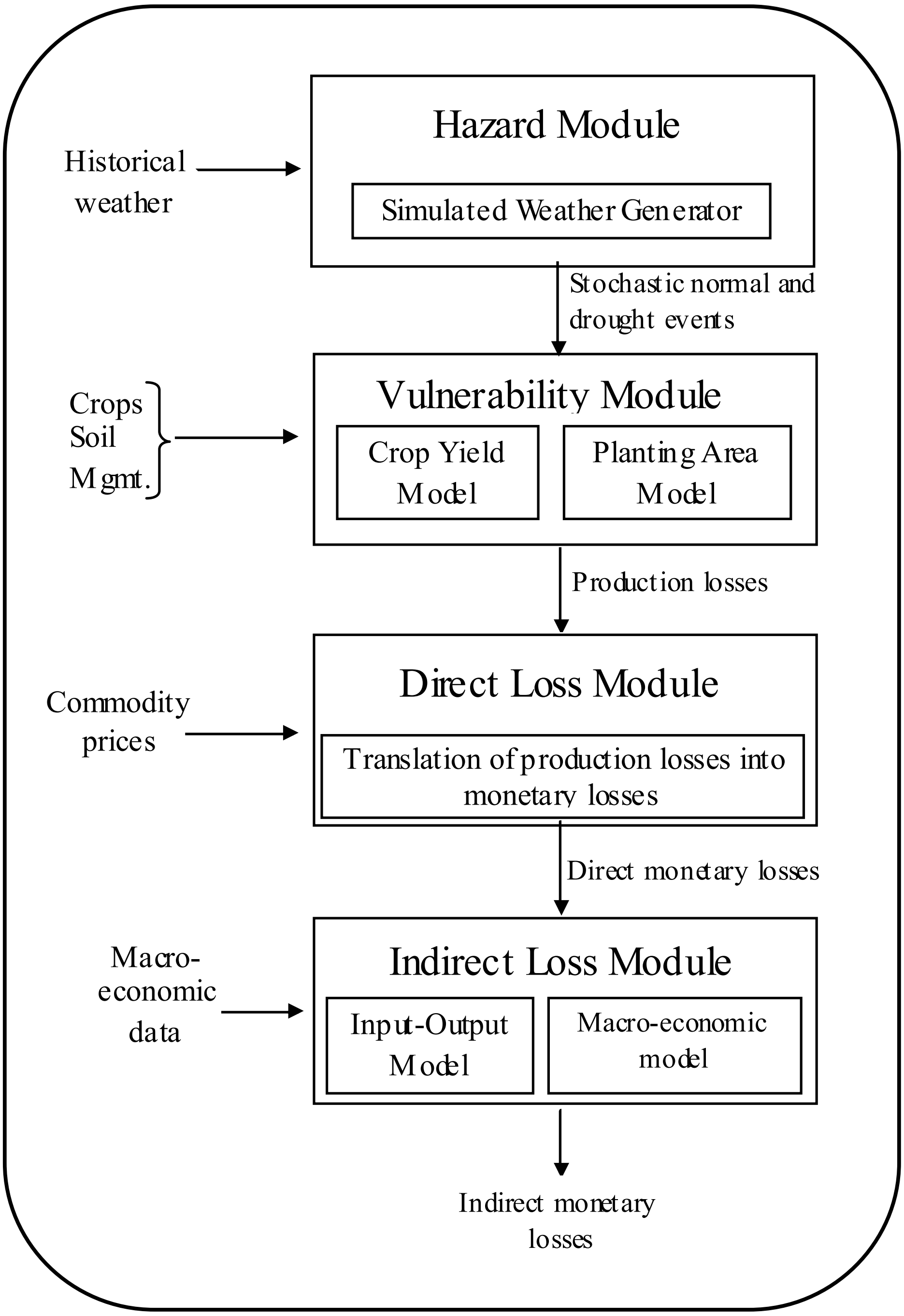
3. The scope and objectives of the study were agreed through extensive consultations with several concerned GoAP departments (Environment, Disaster Management, Planning, Agriculture, Rural Development, and Rains-Shadow Area Development) and others stakeholders, as to *complement the existing state and central government programs* by enhancing state's *capacity to assess the long-term impacts of drought and raise resilience* at different levels to drought risks. The study aims 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 Government of Andhra Pradesh in the development of *a forward-looking and anticipatory strategy for adapting to frequent drought events* and the conditions of water deficit.

4. In addition to the macro-economic 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 as a result of human-induced climate change. Thus, this study is linked to a larger program of work in a new strategic area by the World Bank on adaptation to climate variability and longer-term changes.

Methodology

5. The probabilistic drought risk assessment model developed for this study consists of the four modules, as described on Figure S.1.

Figure S.1: Probabilistic Drought Risk Assessment Model



6. The model developed for this exercise offers a powerful tool to undertake a thorough drought risk assessment (with statistical outputs such as average annual loss, loss exceedance curve, etc.) 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 on management practices and crop phenology in the eight selected districts of AP. Its validation was very successful for the five major crops in those districts: paddy, maize, jowar (sorghum), sunflower and groundnut. It should be noted that the results presented in this report are aggregated to the district level and, thus, do not provide a fair and full illustration of this model capability to quantify the effect of drought and coping strategies on crop yield and production at the block level.

7. While the approach broadly follows a general catastrophe risk modeling framework used for assessing the impacts of rapid onset disasters (such as cyclones, floods and earthquakes), this study had to customize the framework to a different risk assessment paradigm – the one that can be applied to slow onset disaster, such as drought. One of the particular challenges is in estimating the economic impacts of slow onset events. Contrary to rapid onset disasters, droughts normally lack highly visible impacts; instead, their impacts are generally nonstructural and spread out over long periods and large areas. Furthermore, droughts generate significant indirect losses, as compared to direct losses in crop production.

8. Indirect losses have been estimated through a macro-econometric model and an input-output model. A critical task was to build a bridge between the drought risk analysis at the block level for the eight districts, and the state-wise macro-economic analysis. To this end, a prototype macro-econometric model was developed to explain how the variability of the value of crop production in the eight selected districts impacts the variability of the state-wide Gross Value Added (GVA) in the main economic sectors of AP. The validation of the macro-econometric model was satisfactory, as the estimated agricultural gross value added mirrored the observed agricultural gross value added over the last 10 years, especially during drought years. The input-output model, the first ever developed for AP, was used to give a detailed picture of the linkages between the different sectors and sub-sectors of the economy, the flow of goods and services, and employment.

Key findings

8. ***The study findings highlight the importance of intensifying efforts to support economic and social development of drought-prone areas that is sustainable and resilient to water-scarce conditions in the long-term.*** Frequent drought is a difficult fact of life 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 % chance (or every 2 to 3 years) that the value of crop production output for the five major crops combined – paddy, maize, jowar (sorghum), sunflower and groundnut - will be somewhat less than in a "normal" rainfall year. Loss of crop production output exceeds 5 % of the "normal" year output value every 3 years, 10 % - every 5 years, 15 % - once in 10 years, and 25% - once in 25 years. The Average Annual Loss (AAL) of output due to the drought-prone climate is at 5 % for the eight district region, ranging form 6 % in the worst affected Anantapur district to 3 % in Prakasam. Individual farmers may suffer greater losses if their particular crops happen to be hard hit. Importantly, for many small and marginal farmers in these districts, a loss of output value of 10% or even 5 % - which is shown to likely happen quite frequently - can mean falling under the poverty line. The bottom line is that, despite

a variety of anti-drought programs, the human and social costs of drought have been and remain devastating for millions of people in AP. This suggests the need for enhancing an existing strategy by innovative, forward-looking approaches and tools, to help these people to adapt to frequent droughts.

9. ***Impacts of drought are highly variable and localized.*** In addition to large variations across time series, the impacts vary greatly across locations and crops and depending on drought severity. Modeling highlights significant variations for a particular crop across districts and even blocks within the same district. For example, severe (once in 30 years) drought is likely to reduce rice yields from 29% in Nalgonda to 62 % in Kurnool (see Table S.1). Yield losses of maize, a rain-fed crop, appear particularly stuggering in Anantapur, Kurnool and Mahbubnagar, which are the driest districts with less than 600 mm of rainfall every year. Importantly, different crops can be particularly vulnerable in different districts.

Table S.1: Simulated Rice Yield Losses in Drought Years (% normal year)

	Anantapur	Mahbubnagar	Kurnool	Cuddapah	Chittoor	Prakasham	Rangareddy	Nalgonda
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

10. ***Loses borne by farmers due to drought can be significantly reduced by adjustments in farming practices that reduce water demand,*** such as permanent shift to a larger share of less water intensive crops in the cropping mix. Evidence shows that 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. This is however practiced as a temporary measure with the area of rice typically restored once the drought is over. The model assessed some scenarios of *permanently reallocating water from rice* in order to provide 50 mm irrigation for the four rain-fed crops, included in the model, at one or two critical stages in their growth. In Anantapur, *this strategy is able to 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 changing the cropping pattern, do not appear to have a significant long-term effect on a large scale.

11. ***The impacts of measures that can be adopted by farmers are also 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.

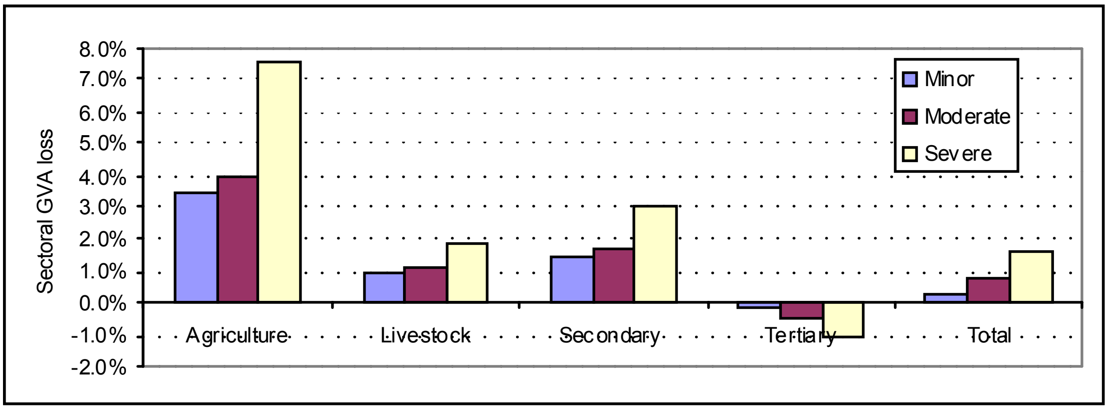
12. ***Location-specific analyses are needed to inform the development of effective drought adaptation plans for affected areas.*** One of the striking findings of the analysis was a degree of variation in drought impacts on different crops in different locations, clearly suggesting that there is a significant scope for increasing the effectiveness of advice to farmers about undertaking drought coping measures, such as switching to alternative crops in a response to 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 demonstrates 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 analytical capability of the model can be further strengthened, as discussed below.

13. ***The longer-term impact of human-induced climate change reinforces the case for shifting to less water intensive crops in the drought-prone districts.*** 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.

14. ***The impact of drought on the overall state economy, measured in Gross Value Added (GVA), is marginal and declining.*** Underlying structural changes in the AP economy are the key reason for this effect. The long-term Average Annual Loss in GVA for the state due to all drought events is estimated at 0.2%, even under the benchmark (business as usual) case. During the years of severe drought, an event which happens once in about 30 years in the eight district region, the loss in total GVA rises to 1.6 %. Sector-wise, the macro-econometric 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, and an even positive impact on the tertiary sector. The trend of the AP economy over the last 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 macro-economic impact of drought will further diminish.

Figure S.2: Conditional Average Loss in Gross Value Added (GVA) due to Drought, %, by Sector and Drought Category (Minor, Moderate, Severe)



Note: Positive numbers/percentages represent loss while negative numbers mean gains.
Source: Study model simulations

15. ***Accelerating an observed structural shift in the AP economy from the agriculture sector towards the secondary and particularly tertiary sectors can be interpreted as a powerful macro-economic drought adaptation strategy.*** The impact of such shift on economy's resilience to drought is examined through several scenarios in the macro-econometric model, corresponding to different shares of the agriculture, livestock, secondary and tertiary sectors in total GVA. The analysis has shown that the loss in total GVA attributed to drought events can be reduced by 80 % in a scenario when the shares of the agriculture, secondary and tertiary sectors roughly approximate the structure of the economy of Brazil, as compared to a scenario of maintaining the current structure of the AP economy. This means that the loss in total GVA can be reduced from 1.6% to 0.2% under severe drought in the eight district region. These encouraging signs in the average macro-level indicators provide an opportunity for the state to more actively and

effectively provide targeted assistance to those whose life and well-being are devastated by drought.

16. ***The above findings are consistent with a growing body of evidence on the macro-economic impact of climate-related disasters.*** As a devastating one time event as it is, the macro-economic impact averaged over time and/or space is usually small. Based on world-wide historical data, a recent study shows that the maximum annual impact of drought is 0.8% of GDP for developing countries as a group. Furthermore, the state-wide economic impact of drought in AP was compared with that of cyclones and floods. The impact of those was assessed by another recent World Bank study that used a similar modeling framework as applies to rapid onset disasters. The annual average loss caused by droughts on the AP economy is lower than that due to cyclones or floods, although any comparison has to be made with caution because losses are not measured in the same unit (loss in GVA for droughts, and loss in public infrastructure and housing for cyclones and floods).

17. ***The analysis gives additional useful insights on the impact of drought on different sectors that can inform government policies.*** Interestingly, the livestock sector is less affected by drought than the secondary sector, due to the inter-dependence of the latter with the agriculture sector. Thus, the future impact of drought on the rural economy can be also moderated due to an increasing role of the livestock sector. This is consistent with the analysis of historical data on past droughts which reveals a declining trend impact on both the overall economy and the primary sector. Furthermore, the macro-econometric model estimates some gains for the tertiary sector (with one year lag) as a result of future droughts. Several factors may account for the boost to tertiary sector production: central government transfers, changes in consumption patterns caused by the drought and an increased supply of labor.

18. ***Optimistic outlook based on aggregated data should not take attention away from immediate significant problems related to drought vulnerability***. Droughts have had and continue to have a negative impact on the performance of the agriculture sector and, thus, the lives of the millions of the rural poor. For example, a survey of communities in one of the poorest and worst affected districts, Mahbubnagar, undertaken by another recent study, shows how, depending on the situation of a particular household, responses 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 the impacts of drought are highly differentiated and require tailored assistance to those in need.

19. ***Furthermore, 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 AP is 5.4, rather high relative to other sectors, and implies that a 1 unit loss in output will result in more than 5 units of employment loss. So any external shock to the agricultural sector has a strong impact on employment. The total employment loss for 2002-03 linked to the drop in the agricultural output due to drought is estimated at more than 44 lakhs. This highlights the need for strategies that specifically target the most affected by drought economic indicators: output and employment in the agriculture sector, and particularly in the most vulnerable districts, mandals and communities.

20. ***Several opportunities exist outside the agriculture sector to mitigate the impacts of drought on employment and income in the short to medium term.*** The analysis of the extensive economic data collected and generated by the study indicates a number of opportunities outside the agriculture sector which could be particularly effective for mitigating the impact of drought. The options that arise from the analysis are: (i) significant employment potential is available in trade and transport (except railways); (ii) investment in the construction sector will increase employment in this and related (cement, bricks, steel) industry; (iii) the labor displaced from the

agricultural sector also has a potential to be absorbed in the mining and quarrying sectors; and (iv) the poultry sector (rather than meat) appears to have performed very well during recent droughts in AP, although all the factors accounting for this performance, as well as the risks to farmers, particularly small farmers, need to be better understood.

Areas for Future Action

21. ***Need for a multi-tiered strategy combining economy-wide and sectoral policies with well targeted efforts at the micro-level.*** Drought is a complex and challenging natural phenomenon. It is an even more complex and challenging socio-economic phenomenon, with diverse, sometimes conflicting, impacts on the micro, sectoral and macro levels. The analysis reveals stark contrasts through which drought manifests itself – at different geographic levels, on different economic indicators, on different crops and sectors, on different population groups, on different measures of human well-being. Thus, an effective strategy to address this phenomenon needs 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 better-off farmers and households are typically better able to use alterative opportunities, such as temporarily changing farming practices or migrating to other sectors, whereas the poorer are least resilient to shocks. While far from being exhaustive, this study highlights some elements of a possible strategy for increasing resilience at the micro and macro levels to the occurrence of droughts and water scarce conditions.

22. ***At the macro level, continue and accelerate the on-going changes in the economic structure*** that 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 the poultry sector*, as an important buffer to absorb the drought impacts on rural economy;
- *Encouraging shift in cropping pattern from rice to less water intensive crops*, in order to reduce vulnerability to drought impacts (including revisiting and addressing perverse incentives associated with current agricultural input subsides and rice procurement prices).

23. In addition, investments (including public investments where appropriate) 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 sub-sectors – can be used to moderate the impact of drought on affected communities in the short to medium term

24. ***The key is to address a growing gap between the encouraging macro-economic trends and the impacts on farmers and communities in drought prone areas***, as highlighted by the analysis. The state-wise 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 opportunity due to drought. Thus, it appears critical to intensify on-going efforts and initiatives as to promote more effective, targeted and coordinated assistance to those in greatest need

25. ***Initiate the development and implementation of drought adaptation plans (DAP) for the most affected areas at the manda/district level.*** At the center of these plans will be measures that promote a gradual shift to more sustainable agricultural practices (e.g. changing cropping pattern in favor of less water intensive crops) and other economic activities that are less vulnerable to drought (e.g., livestock, agro-industry), 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 attainments of affected communities. The planning process, aimed to help communities develop a broadly shared and owned strategy for securing stable and sustainable sources of income and livelihood, ought to involve participatory, community-driven approaches. This initiative should build on the existing successful experiences with community-based watershed management in AP, as well as integrate relevant schemes by different departments to the extent possible.

26. ***Create a supporting institutional and policy framework.*** This planning and implementation process would require commitment and involvement by all levels of government - from 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 start-up costs of transition to different crop, technologies and economic activities.

27. ***Explore innovative micro-financing/insurance schemes for farmers that promote 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, rainfall insurance schemes have been offered by private insurance companies on a pilot basis since 2003. While such innovative risk financing arrangements offer farmers new opportunity to finance their losses, it is however important to ensure that they do not perpetuate the current situation of heavy farmers' dependency on rainfall. A sizable average crop output loss due 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.

28. ***Specifically, two lines of possible innovative financing products are proposed by the study:***

- *Drought adaptation insurance* could provide coverage against risks due to a shift from non-viable farming business to viable (agricultural and non-agricultural) business. This insurance product would thus protect farmers against new sources of risks resulting from a change in their farming practices that are more drought-resilient and less water intensive.

- *Drought adaptation credit* could provide initial capital to shift to 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.

29. ***Develop Decision Support Toolkit for drought management planning.*** A drought risk model developed by this study, complemented by other tools and methods (such as a real-life drought forecasting system developed by CRIDA), could provide a good scientific and information basis for supporting drought adaptation and management planning at the block level.

30. ***Strengthen the model, developed by this study to increase its value as a planning and decision support tool*** A rather limited (from the point of view of model capabilities) analysis undertaken in this report suggests that this tool can be very helpful in understanding the consequences of drought in the different sectors of the economy, quantifying such impacts with respect to the drought severity, and investigating the effectiveness of risk coping strategies, at both micro and macro level. The stochastic dimension included in this model also allows to

capture the underlying uncertainty related to weather events, including the impact of anticipated permanent changes in climate. The innovative framework developed under this study, which expands previous work on catastrophe modeling to drought, can be used to address the issue of drought in other states of India and in other drought prone countries.

31. ***The main areas for model development*** are identified as follows:

- *Enhance capability of the agro-meteorological model* by (a) incorporating a more advanced farm behavior model instead of a simplified planting area model; and (b) include a larger number of alternative crops. This would allow to determine economically viable strategies for individual farmers and at an aggregated level;
- *Refine macro-econometric specifications* on a larger dataset to increase the predictive power of the economic impacts of the model
- *Assess and devise applications for agricultural insurance*: One of the main problems with effective crop insurance world-wide is the complexity of agricultural risks, particularly drought, and the lack of adequate risk modeling technology to understand the impact on crop yields. The probabilistic drought risk model may thus create new, until today non-existent, growth opportunities for commercial agricultural (crop) insurance.

Chapter 1: Introduction

1.1. Drought sets off a vicious cycle of socio-economic impacts beginning with yield/crop failure, unemployment, erosion of assets, decrease in income, worsening of socio-economic conditions, poor nutrition and, subsequently, decreased risk absorptive capacity; 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 1950s as evidenced through programs such as the Desert Development Programme, Drought Prone Areas Programme, National Watershed Management Programme for Rainfed Areas, National Calamity Contingency Fund, and National Agricultural Crop Insurance Scheme. However, the human and social costs of droughts remain devastating. And following a major drought in the summer of 2002, the worst since 1987, India-wide economic growth in the fiscal year 2002/2003 recorded a significant slowdown.

Drought in Andhra Pradesh

1.2. Andhra Pradesh (AP) is the fifth largest state of India with a population of 76 million[1], over 70 % percent of which is rural. Agriculture has been historically of key importance to the economy of AP and food security of all India. Irrigated by three major rivers Krishna, Godavari and Pennar, the state ranks among the top five in terms of cultivable land and is among the top producers of rice and fruit. It also leads all other states in the poultry sector.

1.3. AP is also one of the three states in India with the largest drought-prone land area.[2] The state falls under the semi-arid region of peninsular India and is broadly divided into three regions - Coastal Andhra (comprising 9 districts), Teleangana (10 districts) and Rayalaseema (4 districts). During a major drought of 2002, 22 of the total 23 districts in AP reportedly had less than 75% of the normal rainfall during the monsoon season.

1.4. Stress on water resources, especially acute during low rainfall years, has been further exacerbated in the past decades, as demand for water has increased sharply due to growth in agricultural production, population, and the industrial and urban sectors. Particularly worrisome is the over-exploitation of groundwater for irrigation in certain pockets and the gradual decline in the ground water levels causing wells to dry up in the dry season. This impact is being felt most by the farmers, agricultural laborers and the rural community in dry-land rain-fed areas. Lately, there have also been increasing problems with water supply on a larger scale, including urban centers.

1.5. Over the last three decades, the number of groundwater wells has increased from 8 lakhs to 22 lakhs, along with the expansion of area irrigated through groundwater from 10 lakh hectares to 26 lakh hectares. This pushed up an overall level of groundwater exploitation in the state from 16% to 43%. While there is still significant unutilized groundwater potential in the state as a whole, the development of this resource is spatially very uneven, and there are pockets where groundwater exploitation has exceeded 100%. Most of the development is taking place in surface water non-command areas: the stage of groundwater development in these areas is 56%, as against 16% in surface water command areas, which cover only 5% of the state's geographical area.

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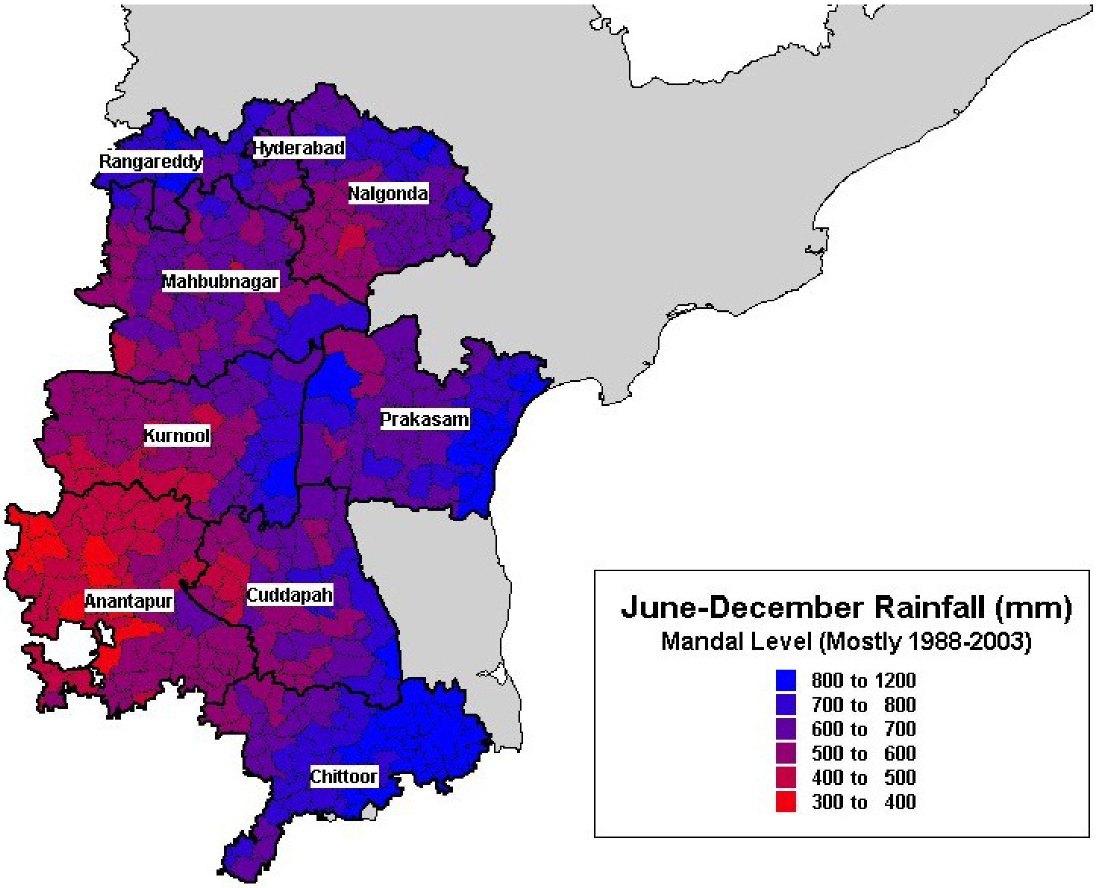
[1] Based on 2001 Census of India

[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). Central Water Commission defines drought as a situation occurring when the annual rainfall is less than 75% of the normal (defined as 30 years average) in 20% of the years examined and less than 30% of the cultivated area is irrigated.

1.6. Out of 23, the eight so called "rain-shadow" districts, with the annual average rainfall well below the state average, are the worst affected by drought[3]. These districts are: all four districts in the Rayalaseema region - Anantapur, Chittoor, Cuddapah and Kurnool; Rangareddi, Mahbubnagar and Nalgonda in the Telengana region; and Prakasam in coastal Andhra (see Figure 1.1).

Figure 1.1: Rainfall Levels and Most Drought Prone Districts in AP



Source: Ministry of Agriculture, Govt. of India.

1.7. For these districts, surface water appears to be rather fully exploited with only a marginal scope for enhancement: the on-going medium irrigation projects will be able to increase the area under surface irrigation by about 8%. The groundwater development in these districts is also quite high, compared to the state average, as illustrated by Figure 1.2: about half of the current total groundwater draft in the state is taking place in these districts. While a large quantum of unutilized groundwater is estimated to be available in surface water command areas and the AP government continues to explore possibilities to increase areas under the surface water command, there are serious technical and economic constraints to increasing the volume of irrigation water for these districts, or at least those areas within these districts that have become drought-prone "hot spots". There is also a wide recognition in AP of the need to start an *adaptation process* of gradual shift to agricultural and other economic practices that are more sustainable under this resource constraint.

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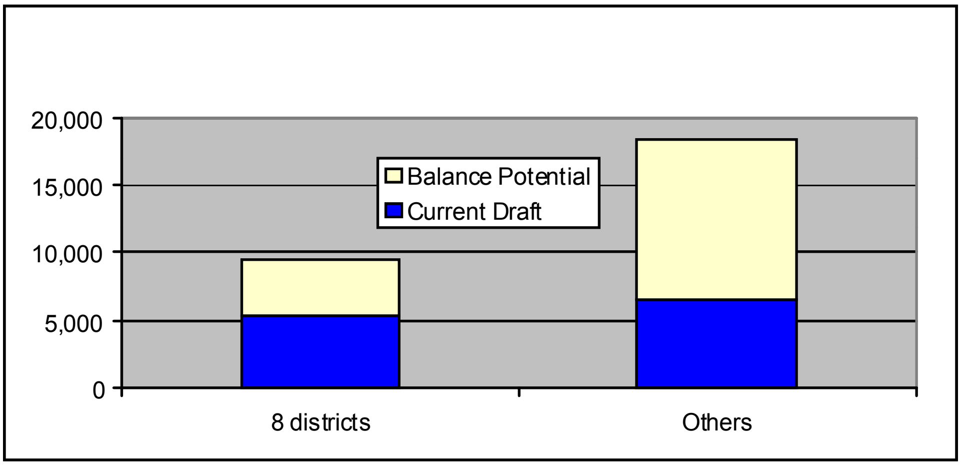
[3] The definitions of droughts are discussed in Annex 1.

Figure 1.2: Groundwater Assessment for Irrigation in AP (Million Cubic Meters)



Source: Report on Estimation of Groundwater Resources in Andhra Pradesh, Groundwater Department, GoAP, 2002

1.8. It is important to add that these districts are home to 35%[4] of the entire population of AP, or about 30 million people. Furthermore, a larger proportion of the population is involved in agriculture, an economic sector most vulnerable to rainfall variability, in these districts, compared to in the other fifteen districts (31 % versus 27%). Specifically, the eight districts account for 43% of the cultivators and 36% agricultural laborers of the entire AP population. While variations in income are significant, the average per capita income for these eight districts is well below the state average (90%), and is particularly low in Mahbubnagar (75%).

AP Government drought related initiatives

1.9. A large number of drought-related initiatives have been on-going in AP with support by Government of India (GOI), Government of Andhra Pradesh (GoAP), and several donors (see Table 1.1 and Annex 2). Examples of major programs include irrigation schemes by the Irrigation Department, the Calamity Relief Fund[5], and the Food for Work Programme by the Revenue Department and the Department of Agriculture. Other important initiatives include the crop seed program of the Department of Agriculture and ground water monitoring undertaken by the Groundwater Department[6]. In 2004, 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.

1.10. There has been considerable experience in drought management at the community level through watersheds programs, sponsored by GoI or/and GoAP, such as the Drought Prone Area Programme (DPAP), Hariyali Watershed Development Programme, Indira Prabha and "*Neeru meeru*", as well as the Joint Forest Management/Community Forestry Programme. In April 2002, the Water, Land and Tree Act promoting water conservation and tree cover was enacted by the AP Legislative Assembly.[7]

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[4] Based on 2001 Census of India.

[5] Revenue (Relief) Department, 1981 & 1995. Drought: A Handbook for Management of Drought.

[6] Groundwater Department, 2003. Note on Ground Water Scenario in Andhra Pradesh.

[7] The Andhra Pradesh Gazette Part IV-B Extraordinary No. HSE/49 Act No.10 of 2002, April 19, 2002.

Table 1.1: Government Programs and Initiatives Addressing Drought In AP

Type of programs	Name of programs
Risk financing	• Crop Insurance • Calamity Relief Fund • National Calamity Contingency Fund
Drought proofing	• Irrigation schemes • Drought Prone Areas Programme (DPAP) • Joint Forest Management/ Community Forest Management • Water Harvesting schemes • Micro-irrigation projects • State-wide irrigation development • Andhra Pradesh Rural Livelihood Project (APRLP) • Watershed Development Programme • Integrated Wastelands Development Program (IWDP) • Rural Infrastructure Development Programme • Jawahar Gram Samridhi Yojna (JGSY) • Sampoorna Grameen Rozgar Yojana (SGRY)
Employment generation	• Self-employment programs on income generation • Employment Generation Mission • Women Self Help Groups • Food for Work Programs (FFW) • Chief Minister's Empowerment of Youth (CMEY) program • Employment Assurance Scheme (EAS)

1.11. Drought related issues have been addressed, to varying degree, by donor- funded rural development programs such as the DFID funded Rural Livelihood Program and the World Bank funded Rural District Poverty Initiatives Project (DPIP) and Poverty Reduction Project. The Hydrology Project helped to organize and maintain the database relevant to water resource and drought management.

1.12. The Department of Planning, with the technical help of CRIDA, 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 cropping patterns, to mitigate these impacts. Research institutions, such as ICRISAT and the Agricultural University, have been conducting extensive research on drought resistant crops, appropriate agricultural strategies in drought prone regions and the socio-economic impact of drought in select rural communities.

Objectives of the Study

1.13. Since both the GoAP and GoI have numerous programs on drought and watershed management, the study was designed as to complement these efforts by enhancing the *long-term* dimension of drought management planning through the assessment of the economic implications of drought and the effectiveness of various policy measures to moderate its impacts at the state and micro levels. The scope and objectives of the study were agreed through extensive consultations with various concerned government departments in AP (Environment, Disaster Management, Agriculture, Rural Development, Rains-Shadow Area Development, Planning) and others stakeholders.

1.14. The objectives of this study are 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 assessment of the impacts under different scenarios; and (c) assist the Government of Andhra Pradesh in the development of a forward-looking and anticipatory strategy for adapting to drought risks and the conditions of chronic water deficit. In addition to the macro-economic and drought management scenarios, the development of the modeling framework aims to account for the possible increase in frequency and severity of the drought risks that may occur as the result of human-induced climate change.

1.15. The study develops and uses a probabilistic risk assessment model that can simulate long-term agricultural and economic impacts of droughts under different climate change and risk mitigation scenarios. Specific steps to develop this model were to:

- Analyze historical data and develop an agro-meteorological model that determines the impact of meteorological droughts on agricultural assets in AP.
- Develop a probabilistic drought risk model that assesses the long-term direct impacts of droughts on losses in production outputs including risk metrics such as probable maximum loss and average annual loss.
- Develop a macro-economic model that captures indirect loss on various sectors of the economy based on the direct loss given by the probabilistic drought risk model.

1.16. Per request by the government, the analysis focuses on the eight drought-prone districts in AP described above. The model offers a powerful tool to undertake a thorough drought risk assessment (with statistical outputs such as average annual loss, conditional average loss by drought category, loss exceedance curve, etc.) and to investigate the impact of alternative farming practices and climate change scenarios in each block of the eight districts. It should be noted that the results presented in this report are aggregated to the (eight) district level and, thus, do not provide a full illustration of this model 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, this decision support tool is expected to be further applied in AP to analyze the drought impacts and various adaptation options in greater detail, as per specific needs of the responsible government departments.

Broader Context of Adaptation to Climate Variability and Changes

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

1.18. A parallel effort is being undertaken by the Bank to assess the climate risks, vulnerability and adaptations options at the national level. A national study, entitled *Addressing vulnerability to climate variability and climate change through an assessment of adaptation issues and options*, includes: (i) a review of current coping strategies of populations already affected by climate variability; (ii) an assessment of the likely impacts of increased climate variability and climate change on the agricultural and water sectors; and (iii) the development of approaches to reduce vulnerability and enhance adaptation to climate related events. The outcome sought for the national study includes a better understanding of issues and options in order to help the Government of India and state governments to integrate the climate risks into development planning and activities.

1.19. The linkages between the AP and national studies are two-fold. On the one hand, the modeling methodology, results and recommendations that are derived from the AP exercise will inform and feed directly into the national study. On the other hand, a larger national program provides an opportunity to extend the dialogue, initiated under this study, and assistance with respect to reducing vulnerability of agriculture and rural communities in AP to climate variability and drought.

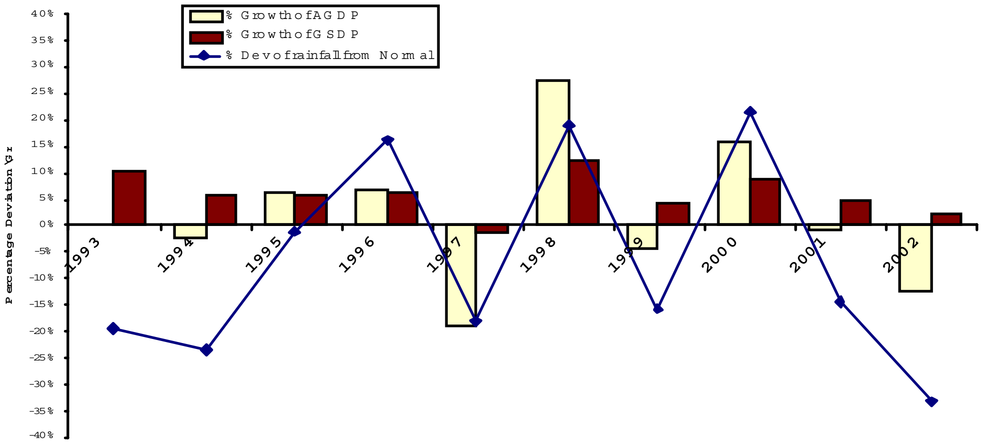
Structure of the Report

1.20. The Report consists of the two volumes: Main report (Volume 1), and Technical Annexes (Volume 2). The main report includes six chapters, starting with this Introduction. Chapter 2 provides a historical overview of the impact of drought on the AP 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 due to drought for the eight selected districts; and Chapter 5 discusses the results of the analysis of direct and indirect economic losses at the state level. Chapter 6 contains conclusions and recommendations.

Chapter 2: Drought And Andhra Pradesh's Economy: Historical Perspective

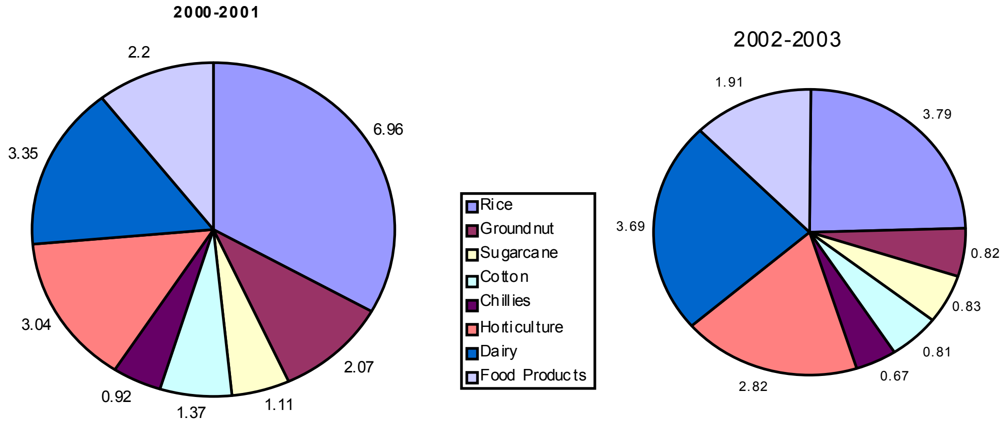
2.1. Drought undoubtedly causes loss of livelihood and human suffering at the individual and community level. Yet, its macro-economic impact is less apparent. The relationship between rainfall and the performance of the AP economy during the period of 1993-2002 is demonstrated by Figure 2.1. The rainfall is represented by percentage deviation from the normal and the economy by two indicators – agriculture Gross State Domestic Product (GSDP) and overall GSDP. In particular, this graph shows that the growth of both agricultural GDP and state GDP slowed down during the drought years of 1997, 1999, 2001 and 2002.

Figure 2.1: Rainfall and Economic Perfomance in Andhra Pradesh



2.2. It is important, however, to look at the impacts at a more disaggregated level. The 2002 drought year saw a decrease in the contribution of agriculture to state GDP, as shown on Figure 2.2. While agriculture contributed to about 21 percent of GSDP during the 2000-01 normal year, it decreased to about 15 percent the following year, which was a severe drought year. In particular, the contribution of water intensive crops like paddy decreased from about 7 percent in 2000-01 to about 4 percent in 2002-2003.

Figure 2.2: 2002 Drought in Agriculture



Total contribution of 21.02% in Gross State Domestic Product

Total contribution of 15.34% in Gross State Domestic Product

2.3. The economic impact of past droughts in AP can also be captured through a comparative study of value of production output (VOP) tables. Sector-wise VOP tables were estimated for normal year 1998-99 and drought year 2002-03, at constant prices for 1998-99 (see Figure 2.3). The effect of 2002-03 droughts is apparent in the changes in VOP of different sectors.

Figure 2.3: Sector-Wise VOP, Constant 1998-99 Prices (Rs. Lakhs)

Sectors	*VOP 1998-99*	*VOP 2002-03*	*% change*
Paddy	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%
Agriculture	***3,073,906***	***2,251,601***	***-27%***
Livestock	948,749	1,677,690	77%
Forestry and logging	167,625	170,715	2%
Fishing	351,600	583,779	66%
Mining & Quarrying	341,449	560,930	64%
Primary sector	***4,883,329***	***5,244,715***	***7%***
Construction	1,022,581	1,524,684	49%
Secondary sector	***8,077,322***	***9,949,970***	***23%***
Tertiary sector	***7,426,711***	***9,844,996***	***33%***

2.4. The agriculture sector has been the worst hit by the 2002 drought – its VOP declined by almost one-third. The production of paddy has decreased to such an extent that the state needed to import paddy. Similarly, decline in output of other food grains and food crops also resulted in imports from other states. The intermediate consumption of paddy and other food crops has declined by 24% and 2% respectively. The private final consumption expenditure on paddy has also declined by 2% for the year 2002-03 in absolute terms in spite of about 8 % increase in population.

2.5. Contrary to agriculture, the livestock sector experienced a rise of 77% in the production despite drought. While this could be due to some government interventions in the poultry sector, which performed especially well, this points out to a potential for greater resilience to drought in this sector. Figure 2.4 gives an additional insight on the impact of drought on livestock vis-à-vis agriculture. It compares the annual changes - with respect to the previous year - in gross valued added (GVA) of the agricultural sector and the livestock sector over the period of 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 1997-1998 and 2002-03 clearly affected the agriculture sector, with a loss in GVA higher than 20%, while these drought events did not significantly impact the livestock sector.

2.6. This data indicates that a structural change in the primary sector activities, such as diversifying into the livestock production, will likely 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 has experienced a rise (+7%) despite a drop in agricultural sector performance.

Figure 2.4: Percentage Changes in Agriculture and Livestock Gross Value Added (GVA), 1993-94 Constant Prices

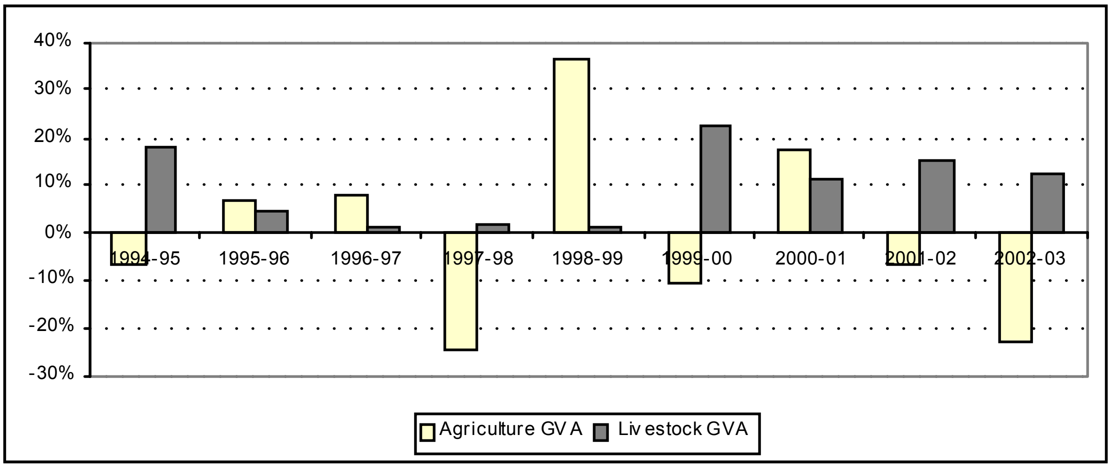
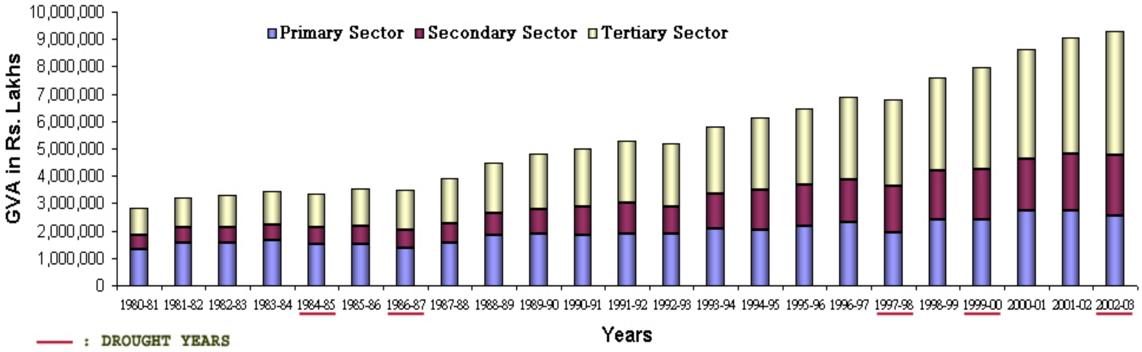


Figure 2.5: Sector-Wise Gross Value Added (GVA) Time Series, 1980-2003, 1993-94 Constant Prices



2.7. Another perspective on the impacts of droughts over time is given by Figure 2.5 The structure of Andhra Pradesh economy and the impact of drought is shown in terms of changes in the gross value added (GVA) in various sectors of the economy and interrelations between them over the period of 1980-2003. The key drought years are marked for quick identification. Each of these years can be compared with the preceding normal/drought year to assess the impacts on the overall economy and across the three aggregate sectors – primary, secondary and tertiary. Importantly, while the agriculture GVA is shown to be lower every drought year as compared to the previous year, the two latest droughts (1999-2000 and 2002-2003) did not cause an absolute reduction in the overall state GVA.

2.8. An apparently increasing resilience of the overall state economy to drought can be explained by another important observation from Figure 2.5. That is, the share of agriculture in the overall economy has gradually decreased while the share of the secondary sector, and particularly, that of the tertiary sector, increased significantly. This trend suggests that the impact of drought on the overall economic performance of the state economy is diminishing over time as the impact on agriculture will be under check by other sectors of economy.

2.9. To summarize, droughts have had and 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 the rural poor. However, the impact of drought on the overall economic indicators has lately been declining due to structural changes, such as the rise 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 an increasing role of the less vulnerable livestock sector. It is therefore important to build on these encouraging signs in average macro-level indicators in order to more effectively provide targeted assistance to those whose life and well-being are devastated by drought.

Chapter 3: Methodological Framework

3.1. A methodological framework developed for this study aims 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. The drought risk assessment model that has been developed can be decomposed into four main modules, as described in Figure 3.1.

Overall approach

3.2. 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 (e.g., minor, moderate, severe drought) are captured from this time series and their frequencies are calculated. The model also includes a capability to simulate different climate change scenarios.

3.3. The vulnerability of the agricultural assets (e.g., crops) at risk to simulated weather events is estimated from a crop yield model and a planting area model. The crop yield model simulates crop yields for different drought events. Farmer's crop planting decisions are estimated through a planting area model. Production is defined as the product between crop yield and cropped area in weight units. 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.

3.4. The direct loss module converts weight units to value units taking commodity prices into consideration. Direct monetary losses are calculated and then risk metrics are estimated: average annual loss, exceeding probability loss, probable maximum loss, etc.

3.5. 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 macro-econometric model and an Input-Output model. The macro-econometric model aims at estimating the impact of crop production variability on the variability of the gross value added 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 sub-sectors 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.[8] The indirect loss module links direct monetary loss estimates at the block level, as assessed in the damage module, with estimated indirect drought losses at the state level.

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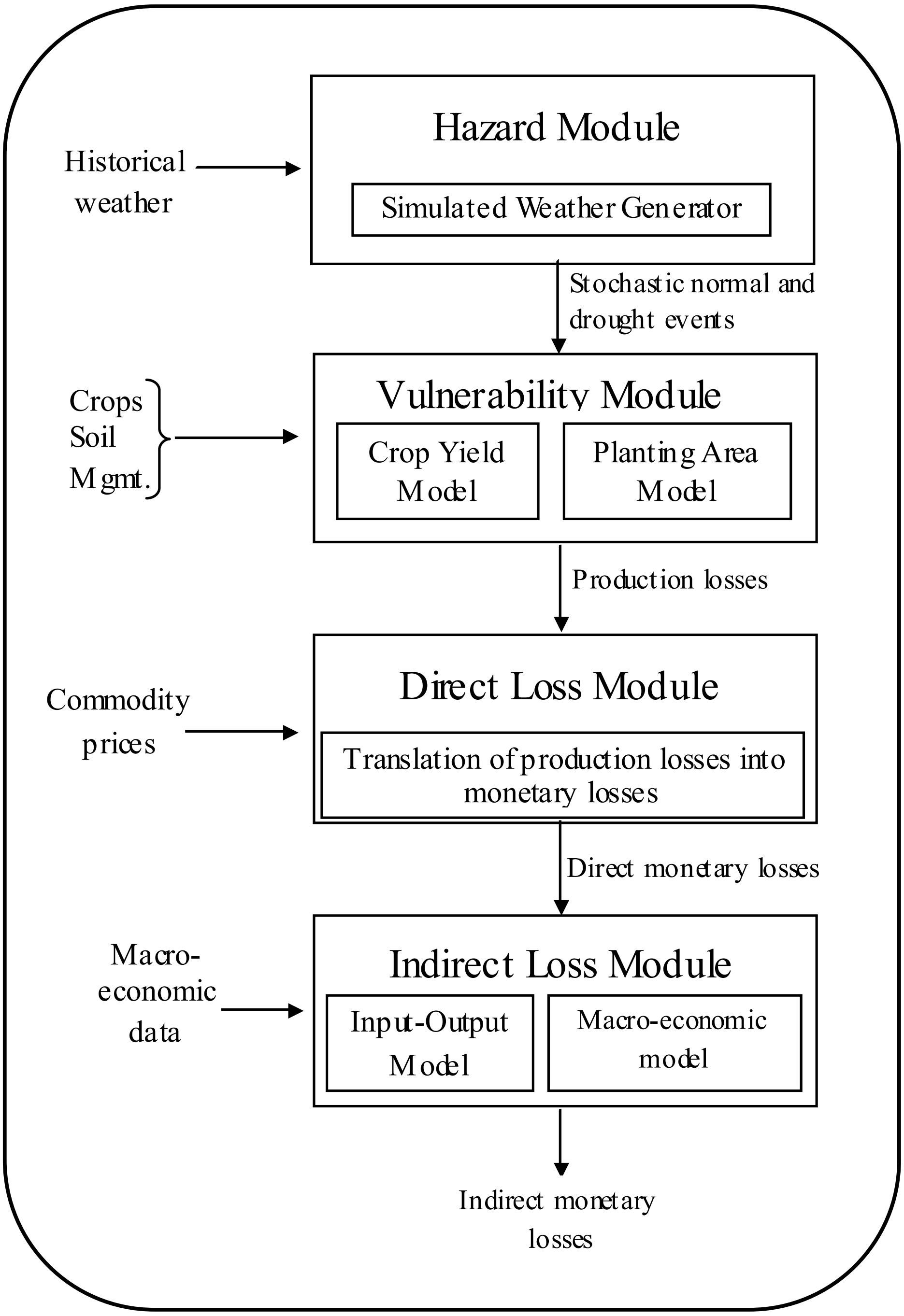
[8] This is the first time ever that such an Input-Output model has been built for the state of AP.

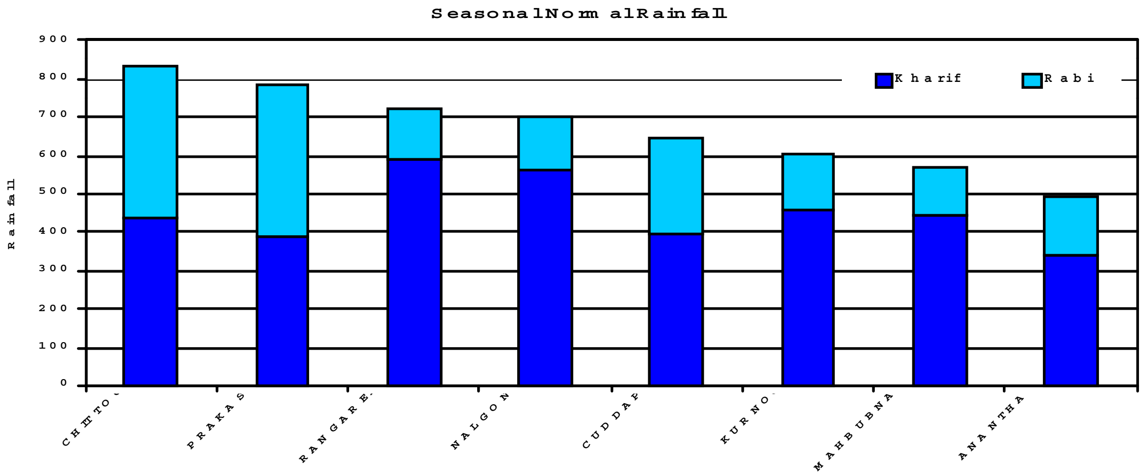
Figure 3.1: Probabilistic Drought Risk Assessment Model



Justification of the eight districts and five crops selected

3.6. The major part of the modeling framework focuses on drought risk analysis in eight most drought-prone districts: Anantapur, Chittoor, Cuddapah and Kurnool in Rayalaseema region; Raggareddi, Mahbubnagar and Nalgonda in Telengana region; and Prakasam in coastal Andhra region (see Figure 3.2). According to Figure 3.2. rainfall in all these districts is well below the AP average of 938 mm (with southwest monsoon in June-September contributing 66% followed by 24% during northeast monsoon season in October-December), and is particularly low in Anantapur and Mahbubnagar.

Figure 3.2: Seasonal Rainfall Deviation in Selected Districts



3.7. The impact of droughts in the eight districts is mainly driven by four dryland crops (jowar (sorghum), maize, groundnut, and sunflower) and one water-intensive crop (paddy). These crops together occupy the largest part of the copped land area inmost of the eight districts (see Figure 3.3). Importantly, these crops contributed 70% of the drop in agricultural production in the eight districts during the last eight drought events. The variability of all crop production in these eight districts is explained at 80% by these five crops (the R2 coefficient of a linear regression between all crops and the 5 selected crops is 0.80).

3.8. The analysis of drought events in the eight districts extends to assessing the economic impact of these events at the state level. In this respect, it is important to note that the eight districts contributed to about 70% of the drop in agricultural production at the state level during the last eight historical drought events (1980-81, 1984-85, 1985-86, 1986-87, 1992-93, 1994-95, 1999-2000, 2002-03). The variability of crop production losses at the state level during these drought years is explained at 88% by the variability of crop production losses in the eight selected districts[9].

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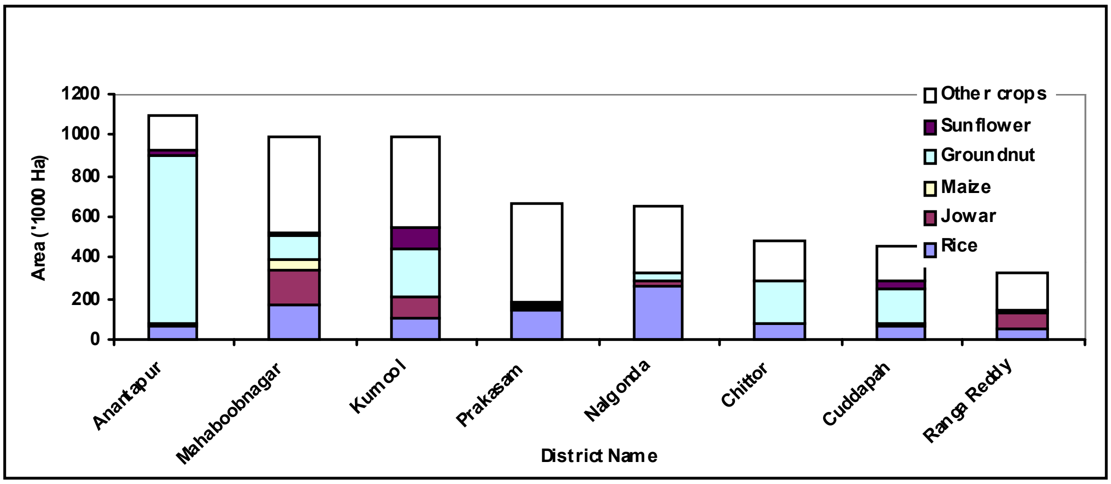
[9] The R^2 coefficient of a linear regression between state crop production losses and crop production losses in the 8 districts is 0.88

Figure 3.3: Area Cropped In Selected Districts



Probabilistic drought risk assessment model

3.9. A probabilistic drought risk assessment model has been developed to estimate the economic impact of droughts and, furthermore, to run different drought mitigation strategies and climate change scenarios. Such models are well established to deal with rapid onset disasters (e.g., earthquakes, cyclones, floods).[10] As explained below, the economic impact of drought is more complex than that of rapid onset disasters because the impact of deficiency of rainfall on agricultural assets (e.g., 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.

3.10. The probabilistic drought risk assessment modeling framework can be decomposed into four modules, following the framework developed for rapid onset disasters, as shown on Figure 3.1.These modules are explained in detail below.

Hazard module

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

3.12. The first step is to define precisely what a drought event is. Several definitions of droughts have been proposed in the literature (see Annex 1). The Standardized Precipitation Index (SPI) based on the precipitation deficit over a specified period of time was selected for this study (see McKee et al, 1993 and Annex 6)). The index quantifies the impact of drought on the availability of different water resources. Soil moisture conditions respond to precipitation anomalies on a relative short time scale (days), while groundwater, streamflow and reservoir storage reflect the long-term precipitation anomalies.

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[10] 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, Orissa).

3.13. 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 the event 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 study region comprising 8 districts. This allowed simulate crop yields in different states of drought through an agro-meteorological model.

Table 3.1: Drought Events and SPI Values

SPI values	Event
-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

3.14. The frequency of drought over periods much longer than the period of observation can be calculated by using a stochastic weather generator. The simulation in this study was based on about 30 years data (see Annex 3). This was done using the weather generator WXGEN, which is embedded in the agrometeorological model, EPIC (see Annex 4). The weather generator 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 6).

Table 3.2: Simulated Return Periods (in Years) of Droughts in Drought Prone Districts

District	Minor	Moderate	Severe	Extreme	Any
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
8 districts	6.8	8.2	38.5	--	3.3

Source: Model simulations based on historical data

3.15. 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 AP, as well we the entire study region.. The results were validated by comparing the historical and estimated exceedance probability (EP) curves, which have shown a good match (see Annex 6). According to simulation of future events, minor drought is most frequent in Anantapur, moderate in Mahbubnagar, and severe drought in both these districts. Importantly, due to rainfall aggregations from block to district and then to the region of 8 districts, the drought category (minor, moderate, etc.) in a block does not necessarily translate to the same category at district and region. Similarly, return period of a drought category for a block need not be the same for the district as well as the region.

Table 3.3: Livestock in AP

Census year	Total livestock (in thousands)	%Change
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%

Vulnerability module

3.16. This module quantifies the damage caused to each asset class by the intensity and duration of a given drought at a site. It should be noted that drought mainly affects flow items, like crops, while rapid onset disasters cause main losses among stock items. The development of asset classification in case of drought is based on a combination of crops and sensitivity to water.

3.17. In addition to the five selected crops, livestock was also considered, as drought directly impacts the productivity of livestock. by affecting the availability of drinking water, fodder, etc. Area, yield and production data are available from Directorate of Economics and Statistics (DES) of Andhra Pradesh for the last 3 years at *block* level and for the last 10 years at the district level. However, these data are available only on an annual basis. Livestock data are provided through the 4-yearly livestock census of AP of 1993 and 1999 at district level. An analysis of the livestock census of AP since 1951 does not show the impacts of droughts conclusively (see Table 3.3). The lack of annual livestock data precluded any direct quantitative assessment of the impact of drought on livestock. It is captured indirectly through the macro model developed in the economic module.

Crop yield model

3.18. In this study damage is measured by the loss in yield of the selected crops. Loss of yield could be estimated from simple statistical relationships between yield and drought / non-drought categories. However, since the study aims to analyze a wide range of response options and eventually the effects of climate change, statistical relationships would not suffice as they would not 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.

3.19. A number of models were considered on the basis of whether they were well established and tested in practice, were likely to be maintained over the next 5 to 10 years and were suitable for application in drought prone agricultural systems such as those in Andhra Pradesh. These included the Decision Support System for Agrotechnology Transfer (DSSAT) suite of models maintained by the International Consortium for Agricultural Systems Applications (ICASA) and the EPIC (Erosion Productivity Impact Calculator) model developed by scientists from the United States Department of Agriculture (USDA) Agricultural Research Service (ARS), Soil Conservation Service (SCS), and Economic Research Service (ERS). Eventually EPIC (Sharpley & Williams 1990; Izarrulde et al. 2003) was selected on the basis that it provided a more coherent modeling environment and there was relevant experience available to the team in the application of EPIC in relevant parts of India (Priya and Shibasaki 1998a & b).

3.20. EPIC was originally designed to assess the effect of soil erosion on productivity. It 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: weather generator (WXGEN); hydrology, erosion and sedimentation, nutrient cycling; crop growth; tillage; economics; and plant environment control.

3.21. The five crops – rice, groundnut, sunflower, maize and jowar (sorghum) –selected for analysis in this study had already been included in EPIC, but needed to be modified to reflect AP conditions. About 47 parameters related to crop phenology, its environment and crop growth in a stressed environment are used in EPIC. Some are used mainly to estimate outputs not used in this study such as nutrient levels at various times in the growing season etc. 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 the ANGR Agricultural University, Hyderabad. Annex 4 provides detailed technical information on the EPIC model and its application in this study.

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

Planting area model

3.23. Planting decisions are taken by farmers at the beginning of the season based on economic parameters (e.g., expected commodity price at harvest) and agro-meteorological parameters (e.g., onset of monsoon, expected rainfall levels). Production flexibility is integral to the practice of dry-land farming (Jodha 1981). When crop failure is foreseen, farmer change their cropping patterns in order to focus their efforts on crops that have a greater chance in adverse weather circumstances. Such flexibility is demonstrated by the farmers in the semi-arid tropics of India (Walker and Ryan 1990). Farmer's plans for rainy season are contingent on rainfall. As a result, the relative importance of rainy and post-rainy season cropping fluctuates from season to season. As a result, the area of Kharif season crops is very variable. However, while this is a source of production variability, the area variability is itself not a source of risk but a pro-active response to weather risk. Another example of area variability given by 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 window of about 2-4 days after the onset of monsoon that is available for planting. Gadgil et al. (1988) found that low soil moisture leads farmers to reduce cropped area, increase inter-cropping, increase to short-duration and low water-requiring crops. Therefore, production flexibility is a key feature of farmers' adjustments to weather variability.

3.24. 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 farmer's planting decision is beyond the scope of this study and left to further research. Instead, the purpose of this model is to estimate, through a statistical analysis, the irrigated and rain-fed cropped area given a rainfall scenario. Data available are annual gross cropped areas and gross irrigated areas at district levels from 1988-89 to 2002-03. Unfortunately, seasonal data are not available. Several models were tested and the selected model estimates the percentage change of gross cropped area and irrigated area with respect to percentage change of the annual cumulative rainfall level (see Annex 5).

3.25. Crop production losses are 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 *block* level. Losses are then aggregated to various levels of administration (district, state) as required.

Direct loss module

3.26. The direct impact of drought is the monetary losses to farmers caused by reduced production. Production losses are converted to monetary losses taking current market price of each crop into consideration. The direct monetary losses are then aggregated to various levels of administration. At this stage of modeling, a table known as event loss table (ELT) is constructed with columns of Event Number, Severity, Frequency and Loss.

Box 3.1. Risk metrics

Average Annual Loss (AAL). It is the expected loss per year when averaged over a very long period (e.g., 100 years). Computationally, AAL 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. In probabilistic terms, the AAL is the mathematical expectation.

Loss Exceedance Curve (LEC). This represents the probability that a loss of any specified (e.g. monetary) amount will 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.

Probable Maximum Loss (PML). This is a subset of the LEC value, which 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 (e.g., 1 in 100 years). The PML is thus the 100 year loss.

3.27. Since large uncertainties are inherent in model estimates of event severity and frequency characteristics, and of 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 (See Box 3.2). The stochastic crop production loss model is detailed in Annex 6.

Indirect loss module

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

Input Output Table

3.29. An inter-sectoral input-output model was developed for the State of Andhra Pradesh. This model measures the inter-actions between the economic sectors of AP. Such table has been constructed by the Central Statistical Organization for India economy since 1973-74. However, this is the first time that this exercise is done for the State of AP. The table was prepared for the following sectors: 1) Agriculture - Food crops; 2) Non-Food Crops; 3) Mining; 4) Food processing industries; 5) Fertilizers; 6) Metal and Metal product Industries including capital goods; 7) Other manufacturing products; 8) electricity Gas and Water supply; 9) construction; 10) Trade, hotels and Restaurants; 11) Transport, storage and communication; 12) Financial and other business services; and 13) Community, Social and other services. The Input-Output table was prepared for the year 1998-99 and the updated for the year 2002-03 using most recent data available (see Annex 7).

3.30. Table 3.4 presents the employment coefficients and output multipliers calculated from the Input-Output table for year 1998-99. 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 paddy shows that one unit (lakh) increase in final demand of paddy results in increase of 1.45 (lakhs) of gross output in the economy. These output multipliers is the same for maize, and slightly lower for jowar (sorghum) (1.43) and groundnut (1.40).

3.31. The Input-Output table gives a picture of the economy in a particular year. It thus cannot capture the dynamic changes in the economy over time. Such dynamic changes can be captured through a macro-econometric model, as described below.

Macro-econometric model

3.32. The dynamic structure of Andhra Pradesh economy is described in terms of changes in the gross value added (GVA) in various sectors of the economy and interrelations between these sectors. The four major sectors included in the macro-model are the following:

(i) *Agriculture Sub-sector* (of the Primary Sector)
(ii) *Livestock Sub-sector* (of the Primary Sector)
(iii) *Secondary Sector* - including manufacturing (both registered and unregistered), electricity, gas and water supply, and construction;
(iv) *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.

3.33. The purpose of the macro econometric model is 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 state-wise. Specification of a macro model requires postulating structural equations, which describe changes in the GVA in terms of certain variables and changes that directly influence the GVA.

3.34. The gross value added (GVA) is calculated as the difference between the values of output and inputs (at current or constant prices). However, the inputs do not include the consumption of fixed capital.[11] For example, in case of 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, includes consumption of fixed capital as one of the explanatory variables.

3.35. Several specifications of the model in term of sector-wise GVA were tested (see Annex 8) and the model best fitting the observed data over the period 1980-2003 is given as follows:[12]

$$\ln(\mathrm{AGVA}) = \underset{\mathbf{(10.53)}}{1.03 \ln(\mathrm{ACFC})} + \underset{\mathbf{(2.98)}}{0.25 \ln(\mathrm{VOP}_{4,8})}; \quad \overline{\mathrm{R}}^2 = \mathbf{0.73}$$

$$\ln(\mathrm{LGVA}) = \underset{\mathbf{(14.64)}}{0.98 \ln(\mathrm{LCFC})} + \underset{\mathbf{(5.32)}}{0.24 \ln(\mathrm{AGVA})}; \quad \overline{\mathrm{R}}^2 = \mathbf{0.90}$$

$$\ln(\mathrm{SGVA}) = \underset{\mathbf{(8.77)}}{0.72 \ln(\mathrm{SCFC})} + \underset{\mathbf{(4.94)}}{0.37 \ln(\mathrm{AGVA}_{-1})}; \quad \overline{\mathrm{R}}^2 = \mathbf{0.84}$$

$$\ln(\mathrm{TGVA}) = \underset{\mathbf{(26.05)}}{1.33 \ln(\mathrm{TCFC})} - \underset{\mathbf{(-2.70)}}{0.12 \ln(\mathrm{AGVA}_{-1})}; \quad \overline{\mathrm{R}}^2 = \mathbf{0.98}$$

[From the t-distribution on 8 d.f. $P(|t|>1.86)=.05$]
where *ln* is the natural logarithm; $\mathrm{VOP}_{4,8}$ is the value of output of the four crops (paddy, maize, jowar (sorghum) and groundnut) in the 8 selected districts; AGVA is the agriculture gross value added, LGVA is the livestock GVA, SGVA is the secondary sector's GVA and TGVA is the tertiary sector's GVA, and AGVA_{-1} is last year's agricultural GVA; ACFC, LCFC, SCFC and TCFC are the consumption of fixed capital in agriculture, livestock, secondary sector and tertiary sector, respectively. Numbers in parenthesis are the p-values and $\overline{R}^2$ is the coefficient of determination adjusted for the degrees of freedom.

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[11] The net value added is defined as the difference between the gross value added and consumption of fixed capital.

[12] Other macro-econometric model tested include: regression of detrended data using first differences, and regression of detrended data using ad hoc linear trend over the period 1980-81 to 2002-03 (with a break dummy in 1993).

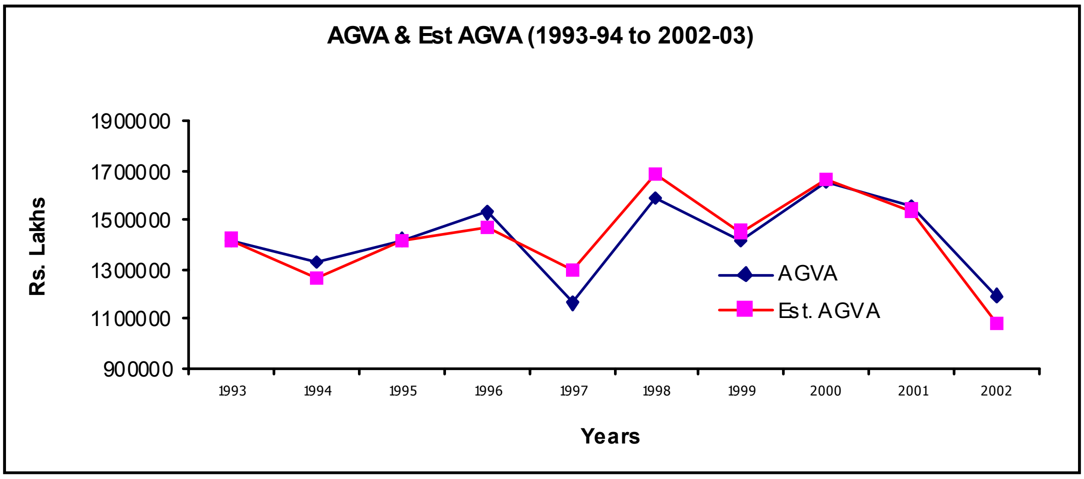
Table 3.4: Employment Coefficients and Output Multipliers 1998-1999

Sectors	Employment coefficients	Multipliers	Sectors	Employment coefficients	Multipliers
Paddy	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	Non-Metallic Mineral Products	0.95	1.95
Other Crops	5.40	1.22	Basic Metals & Alloys	0.05	2.54
Livestock	5.40	1.42	Metal Products, Elect. & Non-elect. Machinery & Equipments	0.06	2.67
Forestry and logging	1.44	1.17	Transport Equipments & Parts	0.59	2.10
Fishing	0.68	1.25	Miscellaneous		2.20
Mining & 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 & 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 & 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	-

3.36. The coefficients were by the method of Seemingly Unrelated Regressions (SUR) and can be interpreted as partial elasticity coefficients. According to the model above, a 1 percent change in the production of the four selected crops in the eight selected districts will generate a 0.25% change in AGVA. Likewise, a 1 percent change in tha agricultural GVA would cause a 0.24% change in the livestock GVA. A 1 percent change in agricultural would cause a 0.37% change in the secondary sector's GVA and –0.12% in the tertiary sector's GVA the next year. This macro-econometric model can explain between 73% and 98% of the variability of the dependent variables. As it can be seen in Figure 3.4, the first equation estimating AGVA captures well the peaks and drops observed over the period 1993-2002.

3.37. It is important to emphasize that because of the statistical limitations of a restricted sample size, the model described above should be viewed as preliminary. Some alternative macro-econometric models tested under this study show a positive but not statistically significant elasticity coefficient of AGVA on SGVA, and a negative but not statistically significant coefficient of AGVA on TGVA (see 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 a larger data series.

Figure 3.4: Estimated and Observed Agriculture Gross Value Added (AGVA)



Chapter 4: Reducing Vulnerability Of Agriculture To Drought In Eight Drought-Prone Districts

4.1. This chapter discusses 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. 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.

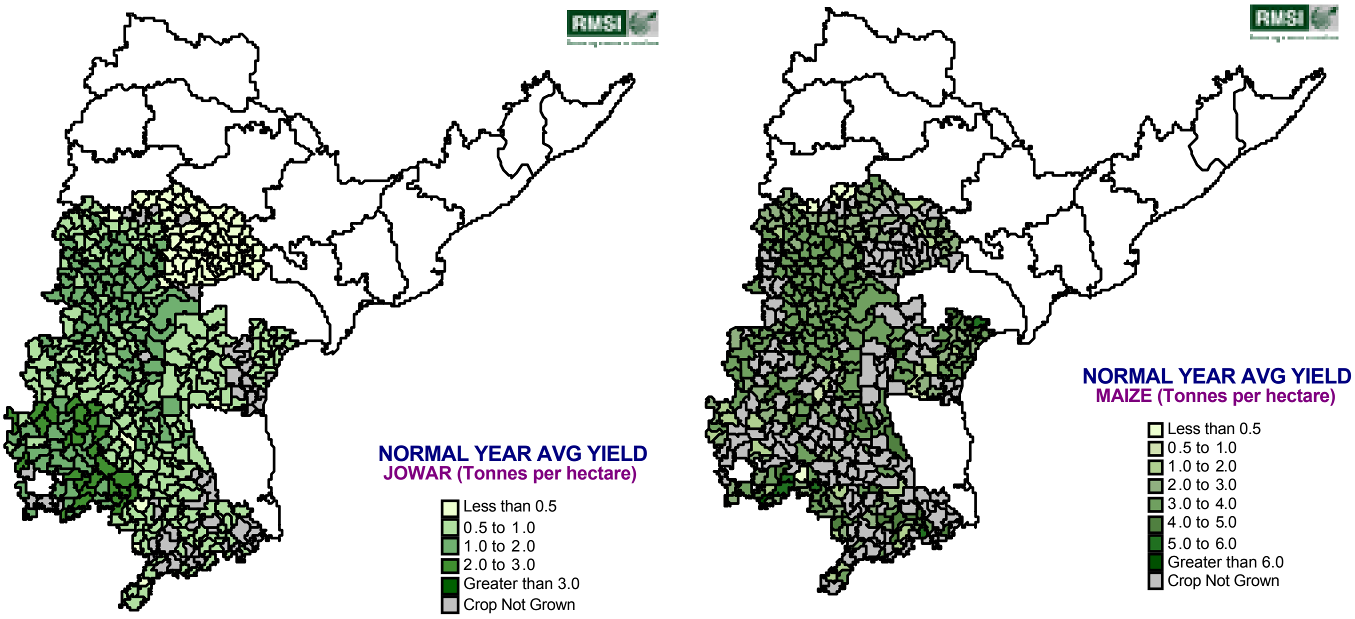
Crop yield variability: benchmark case

4.2. In Andhra Pradesh 68 percent of rainfall is received during the southwest monsoon from June to September, which is the main cropping season in the rainfed areas. Maize, jowar (sorghum), groundnut and sunflower are the major crops grown under rainfed conditions during this season in the drought prone districts. However, rice has been becoming more commonly cultivated in rainfed 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, as well as aggregated at the district level.

Variation in yields at block level

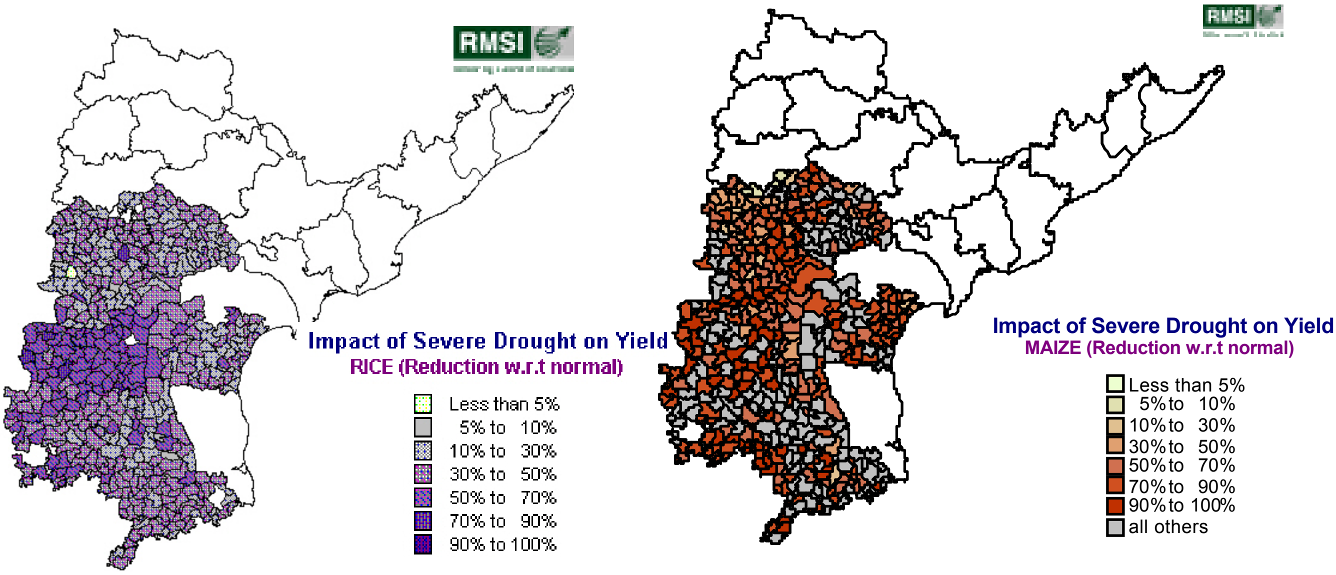
4.3. The yields under normal conditions show considerable variation across blocks and districts for the same crops. Thus, different locations appear to most favor different crops (see Figure 4.1). For example, groundnut does far better in a small region in the north-west, while jowar does better in the south west and sunflower in the north east. Maize does not show significant areas of higher yield.

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



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

Figure 4.2: Impact Of Severe Drought on Yield (% Reduction With Respect To Normal Yield)



Variation in yields at district level

4.5. 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 mandal) specific coping strategies are needed.

4.6. It must be stressed that the model simulates yield and production (yield x planted area) at block level using a relatively simple and coarse model of shifts in planting areas at a block scale, i.e., 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 even more affected by drought than rice. However, during the drought of 2002, the output of crops like jowar, maize and other food grains showed a rise in their volumes 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 cutting on area under water-intensive rice in favor of less water intensive crops. Thus, farmers, using traditional knowledge, common sense and guidance from the Agriculture Department, do *adapt* to rainfall variability.

Table 4.1: Rice Yields in Normal Years and Rice Yield Losses in Drought Years

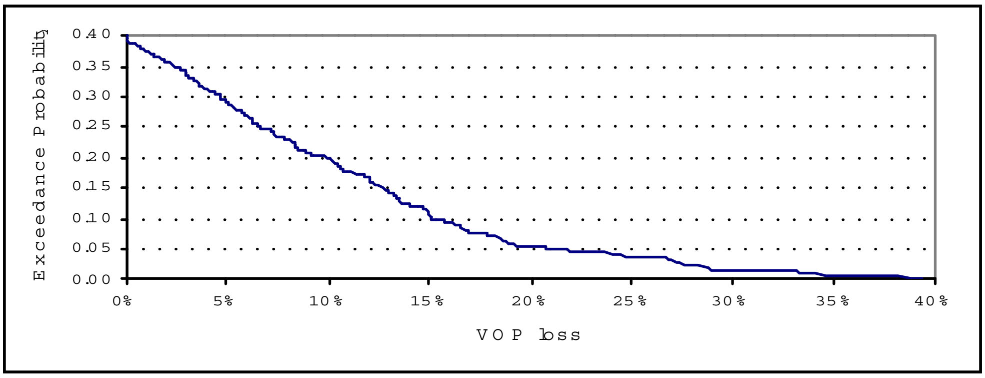
	Ananthapur	Mahbubnagar	Kurnool	Cuddapah	Chittoor	Prakasam	Rangareddy	Nalgonda
Normal (MT/Ha)	2.87	2.15	2.59	2.73	2.86	3.10	2.37	2.69
Yield losses in drought years (% normal yields)								
Minor	14%	10%	13%	11%	10%	10%	19%	8%
Moderate	27%	19%	32%	21%	18%	19%	24%	16%
Severe	45%	26%	62%	31%	35%	33%	31%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

4.7. The key question is how effective their coping strategies are and whether they can be improved. 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, if it were to answer this critical question. An ability of this modeling tool to simulate the behavior of single farmers could be used to assess farm level decisions and help select those economically viable.

Crop production losses

4.8. Figure 4.3 shows the exceedance probability curve of the estimated loss of value of output (VOP) for the region of the eight drought prone districts, defined as the difference between the VOP of the five crops during a normal year and the VOP during a drought year. According to this Figure, the VOP is less than that in a normal year in 40% of the time, i.e., the 8-district region faces a loss in VOP due to drought every 2 to 3 years (2.5 years on average). The VOP loss is as high as over 15% once every 10 years on average and exceeds 25% once every 25 years.

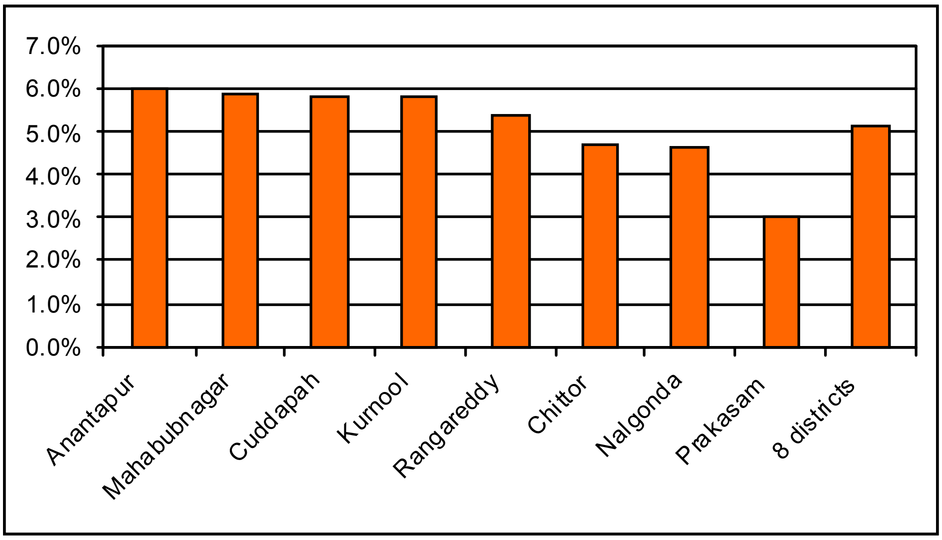
Figure 4.3: Crop Production Losses Caused by Drought in 8 Districts – Exceedance Probability Curve



4.9. The Average Annual Loss (AAL) of output due to the exposure to drought (averaged over a long series of years) is 5 % for the 8-district study region, assuming no changes in the current copping pattern. This is a quite significant value for average loss. The AAL of output raises to 6% in the worst affected Anantapur, closely followed by Mahabubnagar, and drops to 3% in the Prakasam district (see Figure 4.4.). As shown above, there are further variations within districts, across blocks. Even greater disparities in impacts of and resilience to drought can be expected at the farm and household levels. Averages always mean that some individual farmers will suffer greater losses than a district or mandal average if their particular crops are hard hit.

Importantly, for small and marginal farmers, even a 10% or 5 % reduction in output could mean falling below the poverty line.

Figure 4.4: Average Annual Loss of Value of Output by District



4.10. A survey of communities in one of the poorest and worst affected districts, Mahbubnagar, shows how depending on the situation of a particular household, responses may range from a change in farming decisions to migration to extreme cases of starvation, loss of opportunities and health, and even life itself (see Box 4.1). The 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 mandals of the Mahbubnagar district gives insights into how farmers and villagers change their behavior during a drought season:

Irrigation practices

- Increasing the number of tube-wells and with a decrease in the number of traditional tanks and open-wells;
- Increasing the depth of the tube-wells between 200-300 ft (approximately 61- 91 meters) to access lower ground water levels;

Cropping practices

- Decreasing the area cropped due to lack of water and labor where family members have migrated out of the district;
- Temporarily adapting crop cycle to suit the time of rainfall;
- Limited examples of changing to high yield crops, horticultural (sweet orange, mango, acid lime etc.) and mixed cropping which are 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% of total loans) or Self Help Groups – where debts of farmers vary from Rs. 30,000 to Rs. 200,000 (70% is for agricultural inputs and 30% 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 due to lack of fodder or agricultural work for the livestock;

Extreme practices

- Suicide

Source: "A Review of Vulnerability to Climate Change and Adaptation Strategies in India" March 2005, conducted by Winrock International India and funded by the World Bank.

Adaptation strategies at the farm level

4.11. As evident from Box 4.1 and other observations, farmers adapt, to some extent, their irrigation and cropping practices in response to the changing rainfall level and pattern. However, these changes are usually short-term and aimed at surviving the given extreme event rather than preparing for next droughts, or to the chronic conditions of increased water deficit, occurring in some parts the study districts. That the prevailing current practices appear unsustainable in the long-term is indicated by the falling groundwater table, which is now often as deep as 200 to 250 meters. Energy consumption for pumping has become a costly input for rice irrigation and, since power supply to agriculture is heavily subsidized, it both drains state's finances and contributes to power shortages.

4.12. There is a need, thus, for more sustained shift to water conserving practices, In view of the decreased ground water resource and increased energy costs, the government of Andhra Pradesh is taking measures to ensure that water is used more efficiently and demand for irrigation water is reduced. It has already taken an initiative to curb drilling of bore-wells by bringing the WALTA Act, and its new energy policy exempts the rice farmers from free power for the second rice harvest to discourage rice cultivation.

4.13. Rice requires 1,200 mm of water during its growth period with any short fall from rainfall being made up from irrigation. In the simulations in this study 600 mm of irrigation was applied at regular intervals over the 120 day growing season for rice. By comparison, the yield of rainfed crops like maize, jowar, groundnut and sunflower requires only 400-600 mm of water to complete their life cycle, can be increased by irrigating the crops at critical stages with when water stress prevails. Yield of rain-fed crops decrease if the crops suffer moisture stress during critical stages of their life cycle and particularly during early growth or during grain set, which might well happen during a drought year. Their yields however under could be enhanced by applying 50 mm depth of water at one or two critical stages. Yield can be further enhanced by adding fertilizer along with the irrigation water.

Reallocation of irrigation water by reducing rice area

4.14. Alternative uses of irrigation water use are compared below. Two main scenarios ("treatments") were investigated: a single irrigation of rain-fed crops at the flowering stage or its equivalent (Case 1); plus a second irrigation at the time of yield (grain) formation (Case 2). Under these scenarios, the area planted to rice is reduced so that the water saved can be redistributed to other crops, as described in Box 4.2. As noted before, farmers temporarily adopt these practices during low rainfall years; however, the scenarios analyzed here assume that such practices are used in all years. The results are compared with the "baseline" case in which no irrigation water is available for maize, jowar groundnut and sunflower (Case 0) – a typical "real-life" situation during the years of normal rainfall or minor drought.

4.15. To assess the economic impacts, the changes in yield are converted as changes in product value.[13] The economic impacts are measured in terms of reduction in the loss of the value of production (value impacts), where the value impacts are defined with respect to the value of production in normal (non-drought) years.

4.16. Figure 4.5 shows the impact of these treatments on the value of crop production in Anantapur. A single irrigation (Case 1) is clearly effective, as it reduces the production loss for all drought events. For example, implementing single life-saving irrigation (Case 1) would mean that the average loss in production value to farmers across the district would fall from 24% (of value production in normal years) to 14% when a one in ten year drought event occurs. The average annual loss (in value of crop production) across all drought years would be reduced from estimated at 6.7% under the benchmark case (Case 0) to 3.7% under the single irrigation scenario (Case 1). Implementing double irrigation (Case 2) has little additional impact on crop production loss, bringing it down to 3.4%.

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[13] 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; sunflower: 11,900 Rs/MT.

4.17. Furthermore, these treatments considerably increase the long-term average annual value of production across all – drought and non-drought – years: the average annual value gain is estimated at 32% under single irrigation (Case 1) and 47% under double irrigation (Case 2). Therefore, the strategy of partially reallocating water from rice to provide life saving irrigation to less water intensive crops in Anantapur would *reduce by half the average annual loss* of the overall crop production value during the drought years and would *increase the all-year average annual crop production value* by one-third in case of single irrigation and by almost half in case of double irrigation.

Box 4.2. Reducing rice area: assumptions

According to local expert advice, one life saving irrigation can be given to 24 hectares with 50 mm depth of water if one hectare of rice is discouraged, as rice requires 1200 mm 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 condition and the entire 1,200 mm of water required for rice is provided by irrigation.

Two cases are investigated under this risk coping strategy:

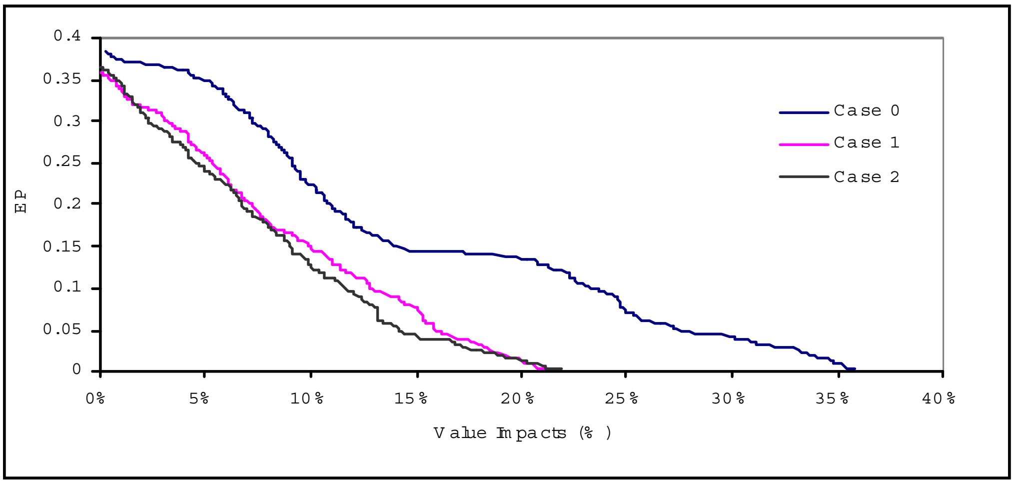
Case 1: One life saving irrigation of 50 mm depth of water is given for 24 hectares of rain-fed area for every 1 hectare of rice. Irrigated area of rice required to be reduced is calculated from the total rain-fed area of the four crops in the ratio of 1:24. The balance of irrigated rice area is left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

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

Cropping areas were reallocated using a simple rule. The area of rice planted was reduced to provide the full area of each of the other crops with one or two irrigations according to the treatment. If there was insufficient rice to yield the necessary savings in irrigation water, the area of the other crops irrigated was reduced accordingly. This strategy of changing the area cropped could be made more realistic taking into account best expected combined value and farmer preferences, but such analyses will be done in a later study.

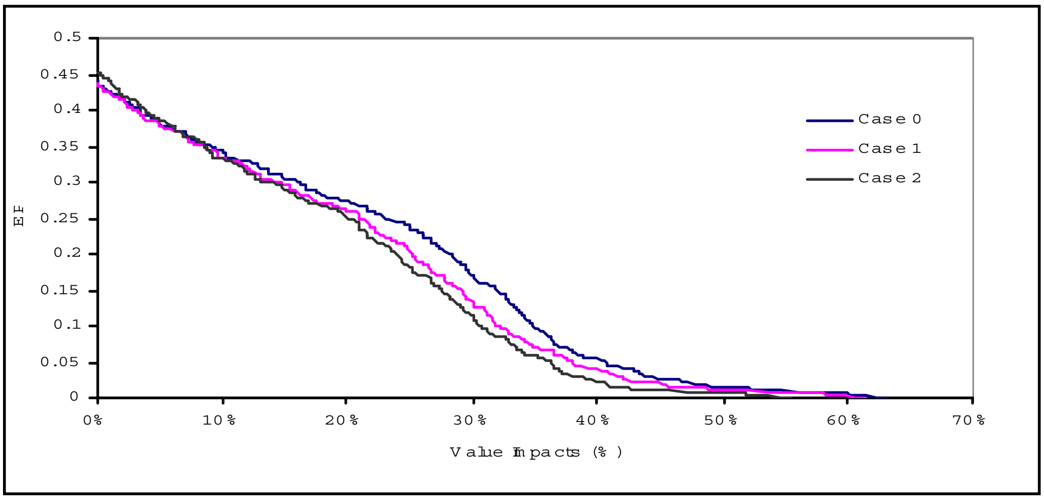
This risk coping strategy is illustrated in Anantapur and Mahbubnagar. Hence, under single irrigation, rice area needs to be reduced by 54% in Anantapur and by 8% in Mahbubnagar. Such a difference is explained by the fact that rice area in Anantapur is less than half that in Mahbubnagar, while the reverse applies to the area under the four rain-fed crops (see Figure 3.3).

Figure 4.5: Reducing Rice Area in Anantapur – Value of Production - Loss Exceedance Curve



4.18. This strategy is much less effective in Mahbubnagar, as shown on Figure 4.6. Implementing single irrigation can lead to a reduction of the value impacts of 3% under drought events with return periods between 4 years (25% frequency) and 10 years (10% frequency). As in Anantapur, adding the second irrigation makes little difference on the loss reduction.

Figure 4.6: Reducing Rice Area in Mahbubnagar – Value of Production - Loss Exceedance Curve



4.19. The reason for greater benefit in Anantapur than in Mahbubnagar can be attributed to the greater proportion of the four rain-fed crops' area with respect to rice. In these runs, a simple allocation based on current land use was used to allocate away from rice to other rain-fed crops. There are many opportunities to explore more finely tuned allocations of water and land to achieve a high value of output, which can be done using this model. The presented results illustrate model's capability (as well as its limitations) and help formulate options for further investigation.

4.20. It should be also noted that the model as of now assesses the effect of switching to the four rain-fed crops only. However Box 4.3, which summarizes research conducted by the Agricultural University in Hyderabad, shows that more complex crop systems and varieties are likely to be needed. These and other options can be built in and assess by the model in the future.

Box 4.3. Farm level adaptation strategies: expert recommendations regarding cropping patterns

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

Soils	Cropping system
Black soils	Cotton + greengram (1:2) Cotton + soybean (1:1)
Red soils	Groundnut + Redgram (7:1 or 11:1) Groundnut + Castor (7:1 or 11:1) Bajra + Redgram (2:1) Setaria + Redgram (5:1) Setaria + Groundnut (2:1)

Crop varieties need also 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
	Greengram	MGG-295, LGG-450, AMG-275
	Redgram	Palnadu, PRG-100
	Horsegram	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

4.21. 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 run for several crops (groundnut, maize and rice) and several districts using recorded rainfall and weather from 1979 to 1998.

4.22. The results show that water retention early in the season was enhanced slightly, but these effects had little impact over the entire season. Yields across all treatments only rarely varied by more than 1%. Minimum till cropping may have other advantages in maintaining soil structure and nutrients and in energy use for plowing (although it often requires additional herbicide treatments), but it appears to have little effect as a drought mitigation technique.

Impact of Climate Change

4.23. Emissions of greenhouse gases, largely driven by human activities, are already affecting 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 and consequently cause a greater risk of both droughts and floods (Intergovernmental Panel on Climate Change (IPCC), 1998, 2001).

4.24. 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 depress production, while others, such as the higher concentrations of carbon dioxide in the atmosphere, 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 AP.

Climate Modeling

4.25. The main tool for making projections of climate change are Global climate models (GCMs) which simulate climate for the entire globe at a resolution of about 300 km by 300 km over India. Higher resolution projections are obtained by running regional climate models (RCMs) for sub-regions 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.

4.26. There are about a dozen different GCMs that have been in use recently. The usual method of testing climate models is to run the model to predict the climate over a baseline period (typically 1961 to 1990). This can be compared to observed climate. Most fail to simulate some important aspects of the Indian climate, however, more recent GCM have improved significantly. RCMs appear to do a relatively better job. In making projections of future climate the circulation models are run for the assumed conditions (i.e. greenhouse gas and particulate composition and concentration in the atmosphere etc) for some period in the future and these results are expressed as a difference from the simulated climate for the baseline period.

4.27. For one of the most commonly used scenarios of global development (the so-called IS92a) the range of GCMs predict for India as a whole an increase in temperature by 2100 of 3 to 6°C and an increase in rainfall of 15 to 40% with the 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

4.28. In AP temperatures are projected to increase by at least 3°C throughout the state by 2041-2060. This increase occurs in all seasons of the year. While rainfall is projected to increase for India as a whole, it is projected to decrease for the drought-prone areas of AP. This decrease is 5% to 20% during the critical monsoon season with a 5% increase during the dry March-May period. The number of rainy days appears to decrease by about 5 to 10%. Rainfall intensity (mm rain per wet day) appears to remain roughly constant over the year but there may be seasonal changes that do not show up in the published data. GCMs are still unreliable in predicting rainfall intensities

4.29. Hydrological modeling suggests a significant reduction in run off (from about 150 mm to 110 mm per year) in the Pennar River basin. This implies serious problems for water supply in the southern AP region. The overall assessment for the drought-prone regions of AP for 2041 - 2060 is for *"chronic water scarcity and drought conditions"*.

Simulation of impacts on yields

4.30. In this study a RCM for India – Hadley Regional Model 2 (HADRM2) - was used to derive projected climate change for southern AP for about 2050. Two simulations of changed climate were generated based on these results by changing the weather generator within EPIC. Both scenarios assume 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 (see Box 4.4). The results are based on 20 years of simulated weather.

4.31. The impact of climate change on crop yields for two most drone-prone districts, Anantapur and Mahbubnagar, is shown on Table 4.2. This impact on yields is the combined effect of increase temperature, decreased rainfall and increased CO_2. There is minor difference in crop yields between the two scenarios. All four rain-fed crops show increased yields under CCS1 (Climate Change Scenario 1), and with the exception of sunflower, little change in CCS2 (Climate Change Scenario 2). Rice shows a decrease in yield by 8 to 9%. Previous studies (Aggarwal et al 2001) also suggested a decline in rice yield under the climate simulated but only by about 5% for the conditions simulated here. The model, along with other models, needs to be analyzed in more detail to determine whether it properly captures the known sensitivity of rice to increases in CO_2 concentration in the air (yield enhancing) and increased temperatures at critical times in its growth cycle (yield depressing).

4.32. 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.

Box 4.4. Climate change scenarios

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

Scenario CCS1:

- Maximum temperature increases by 2 degree Celsius
- Minimum temperature increases by 4 degree Celsius
- Annual rainy days decrease by 5%.
- Atmospheric CO_2 at 550 ppm (parts per million)

Scenario CCS2

- Maximum temperature increases by 2 degree Celsius
- Minimum temperature increases by 4 degree Celsius
- Annual rainy days decrease by 5%
- Cumulative June-September (monsoon) rainfall decrease by 10%
- Atmospheric CO_2 at 550 ppm (parts per million).

Table 4.2: Crop Yield Changes under Climate Change Scenarios: Average results for Anantapur and Mahbubnagar

		Average crop yield change with respect to baseline	
Crops	Baseline scenario	Scenario CCS1	Scenario CCS2
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

Implications for agriculture financing and risk insurance

4.33. 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 (non-mitigated) risk. The findings of this study, related a very high variability of losses across time, locations and crops, and showing a potential to significantly reduce average loss through certain adaptation strategies, have useful implications for designing drought risk financing strategies at the state level, such as innovative insurance products.

4.34. The probabilistic drought risk model developed in this study, based on sophisticated weather, soil, and crop growth information, can be used to forecast the expected yield and loss ratio function over the crop season. It provides a foundation for revisiting agricultural insurance through catastrophe modeling techniques. One of the main reasons why crop insurance has so far been under-developed world-wide 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 a highly location and crop specific phenomena. The probabilistic drought risk model may thus create new growth opportunities for commercial agricultural (crop) insurance, which until today is almost non-existent. As mentioned above, developing a capability to simulate the behavior of single farmers would be another important step in this direction.

4.35. Crop insurance is a sophisticated line of business, as the impact of adverse natural events such a 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 (see 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 underwriting 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.

4.36. The analysis also highlights that while risk financing arrangements offer farmers a valuable opportunity to finance their losses, it is however important to ensure that they do not perpetuate the current situation of heavy farmers' dependency on rainfall. A sizable average crop output loss due 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.

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

- *Drought adaptation insurance* could provide coverage against risks due to a shift from non-viable farming business to viable (agricultural and non-agricultural) business. This insurance product would thus protect farmers against new sources of risks resulting from a change in their farming practices that are more drought-resilient and less water intensive.

- *Drought adaptation credit* could provide initial capital to shift to 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.

4.38. These drought adaptation financial instruments would aim to induce farmers to shift from farming practices that are known to be unviable in the long run because of increasing water stress, exacerbated, in the case of Andhra Pradesh, by global climate change. They would offer the farmers the opportunity to share these new risks, associated with the transition, with the society, as the adaptation process will benefit not only the farmers but also the society at large.

Box 4.5. Weather Insurance in India: Advantages and Caveats

The analysis of Indian Crop Insurance Program between 1985 and 2002 reveal that, rainfall accounted for nearly 90% of total claims in India – 75% on account of deficit rainfall and 15% on account of excess rainfall. Against this background, crop insurance may be a viable risk financing solution to help farmers to absorb their potential losses. However, traditional multi-peril 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 (e.g., rainfall) and not on the individual losses. Rainfall insurance has many advantages, particularly when dealing with small and marginal farmers heavily exposed to drought. Trigger events (like adverse rainfall) can be independently verified and measured. Since India has an independent rainfall reporting system (through Indian Meteorological Department), it can be measured in the most tamperproof environment. This would neutralize moral hazard in data-procurement to a great extent. 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 (KBS) Local Area Bank. In 2004, three insurance companies (AIC, IFFICO-Tokyo and ICICI-Lombard) offered rainfall based insurance products in several states. They insured 7,181 farmers covering a sum insured of Rs. 157.0 million, and earning a premium of Rs. 8.9 millions.

However, such a risk financing product may have limitations in the long term, particularly if the insured crops become more and more exposed to drought as a consequence of a falling groundwater table (or increased rainfall variability due to 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 effects in the pricing of their insurance products. Rainfall insurance may thus give farmers the wrong incentives to grow non-viable 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.

Chapter 5: Managing Economic Impact of Drought at the State Level

5.1. Drought historically 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); decline in agriculture-dependent industries; increased unemployment in agriculture and other drought-affected industries, etc. Such effects are felt by households and individuals, agricultural enterprises, and governments. The impacts of droughts are generally non-structural and spread out over large areas. It is thus difficult to quantify the indirect economic losses associated with droughts.

Assessment of direct and indirect loss potentials: benchmark case

5.2. A prototype macro-econometric model was developed to capture the impact of drought at the state level through its impact on the eight selected drought-prone districts, which are estimated to account for 70% of a state-wise loss in the agricultural production due to drought and explain at 88% the variability of crop production losses at the state level (see Chapter 3). This model aims to estimate the impact of drought on the main economic sectors of AP: agriculture sector, livestock sector, secondary sector and tertiary sector.[14]

5.3. The macro-econometric model is linked to the damage assessment module that is used to simulate the crop production losses caused by droughts in the eight droughts-prone districts. "Losses" mean a reduction in the simulated values that the same indicators would have under "normal" (non-drought) weather conditions.

5.4. Under normal weather conditions, the average annual Value of Output (VOP) of the five crops in the eight selected districts is estimated at Rs. 262,483 lakhs in 2002-2003 prices. On this basis, the macro-econometric model estimates the gross value added (GVA) in each sector of the economy in normal years, as depicted in Figure 5.1. The tertiary sector's GVA represents 50% of total GVA and the share of the agriculture and livestock sector is 20%.[15] These estimates are close to the current economic structure of AP: in 2002-2003, the agriculture and livestock GVA and the tertiary sector's GVA accounted for 24% and 47% of total GVA, respectively.

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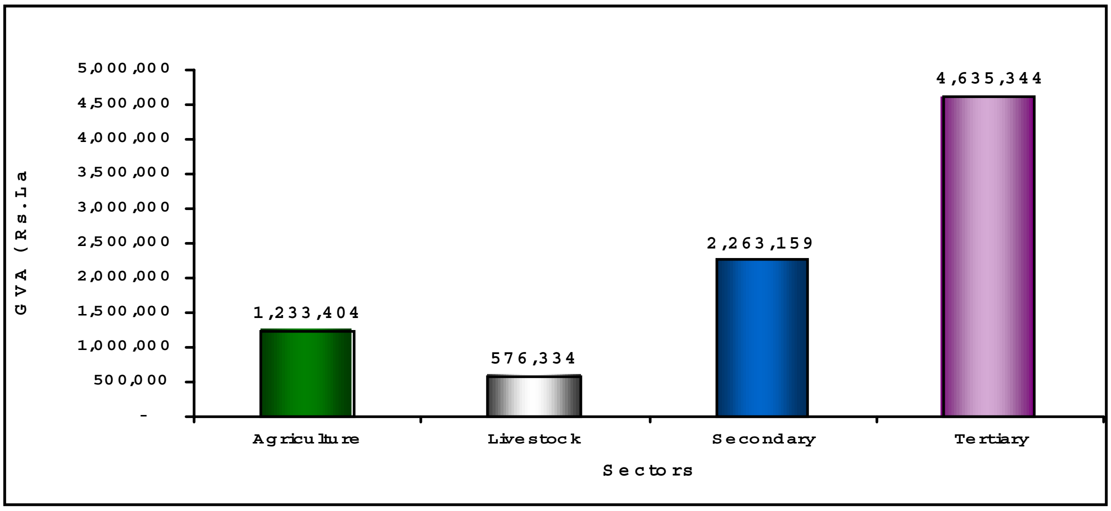
[14] As noted in Chapter 3, the validation of the model on the historical data was successful; however, the specification reported here should be considered an initial test product that should be refined in future applications based on additional data and econometrics techniques.

[15] Other sub-sectors of the primary sector (forestry and lodging, fishing, and mining and quarrying) represent 6% of total GVA.

Figure 5.1: Average Sectoral Gross Value Added (GVA) For Normal Years



5.5. From the assessment of the crop production losses in the eight districts (see Chapter 4), the macro-econometric model translates the impact of these crop losses on the economic sectors of AP, measured in terms of loss in GVA, as described in Chapter 3. The model predicts that a 1% loss in this VOP would cause 0.25% loss in the state-wise agriculture sector GVA; a 1% loss in agriculture GVA in turn would cause 0.24% loss in the livestock GVA. A 1% loss in agriculture GVA of the previous year would generate 0.37% loss in GVA in the secondary sector and 0.19% increase in GVA in the tertiary sector. The latter suggests that droughts may have a positive impact on the tertiary sector (with a one year lag). A number of factors may account for the boost to tertiary sector production: central government transfers, changes in consumption patterns caused by the drought and an increased supply of labor.

5.6. Figure 5.2 shows the long run average annual loss (AAL) in GVA caused by droughts, in percentage terms, 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 a very modest 0.2 %, jumping to over 1 % for the agriculture sector. The largest average damage appears to be caused by moderate droughts, which contribute almost 50% to the AAL in the agricultural sector.

5.7. The macro-econometric model estimates some gains for the tertiary sector as a result of future droughts. This is consistent with the historical data which shows that the tertiary sector is not affected by drought: its GVA increased by 8.9% in drought year 1999-2000 (compared to 8.4% in non-drought year 1999-99) and by 6.7 % in drought year 2002-03 (compared to 5.5% in non-drought year 2001-02)[16].

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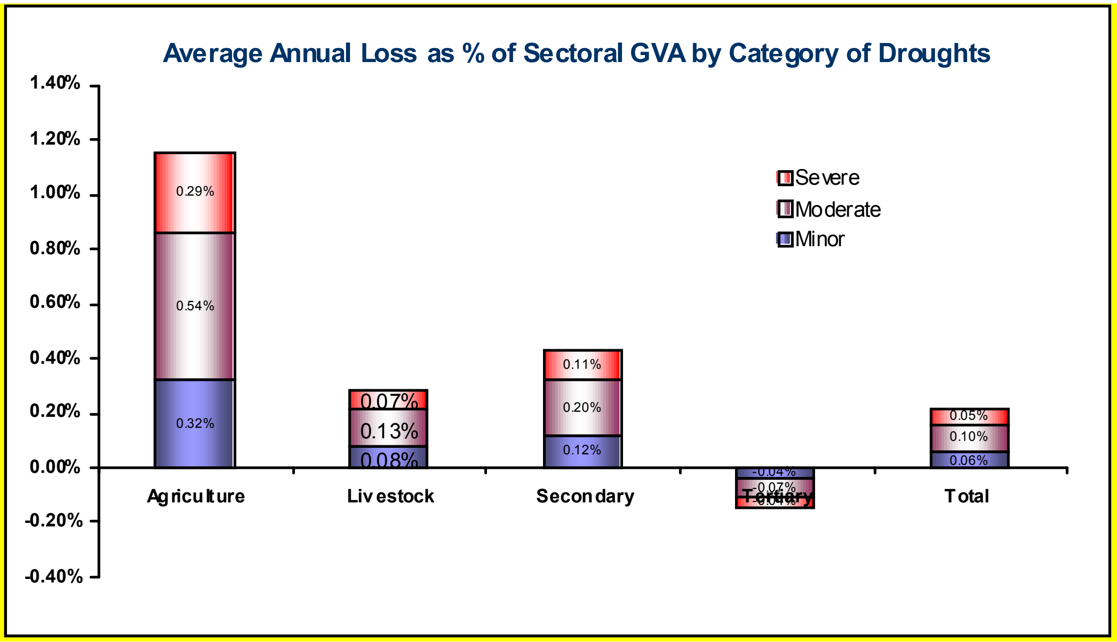
[16] As mentioned in Chapter 3, losses/gains in the secondary and tertiary sector must be best viewed as indicative of sectoral linkages, rather than precise estimate, as estimated coefficients are not statistically significant under alternative econometric models. In this case, the current model may slightly over-estimate the total losses in GVA.

Figure 5.2. Average Annual Loss as % of Gross Value Added due to Droughts



5.8. The positive impact of drought on the tertiary sector may be due not only to the supply side effects captures in the macro-econometric model, but also because of central government transfers through the drought relief mechanisms, as already mentioned above. Table 5.1 shows that the Central Government transferred Rs. 153.5 crores to the state of AP through the National Calamity Contingency Fund (NCCF) in drought year 2002-03.

Table 5.1: Assistance Provided To Drought Affected States from National Calamity Contingency Fund (Foodgrains in Million Tons)

Assistance provided to drought affected Sates from National Calamity Contingency Fund (NCCF)[17]						
State	**2001-02**		**2002-03**		**2003-04**	
	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

5.9. Figure 5.3 further shows the average loss in GVA (as a percentage of the sectoral GVA for normal years) conditional on the occurrence of a drought event (minor, moderate, severe) in the study region, broken down by sector and drought severity. When a minor drought occurs, the conditional average loss is estimated at over 3 % of Agriculture GVA but below 1% of Livestock GVA. In the case of a moderate drought the conditional average loss in the agricultural sector would be about 4% of agriculture GVA and the conditional average loss of the whole economy is estimated at 1 % of total GVA. When a severe drought hits, the conditional average loss is approaching 8 % in the agricultural sector and 2% for the whole economy. At the same time, the tertiary sector shows a gain of 2 %.

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[17] Lok Sabha Unstarred Question No. 151, dated 5.07.2004.

Figure 5.3: Conditional Average Loss in Gross Value Added, GVA, by Sector and Drought Category

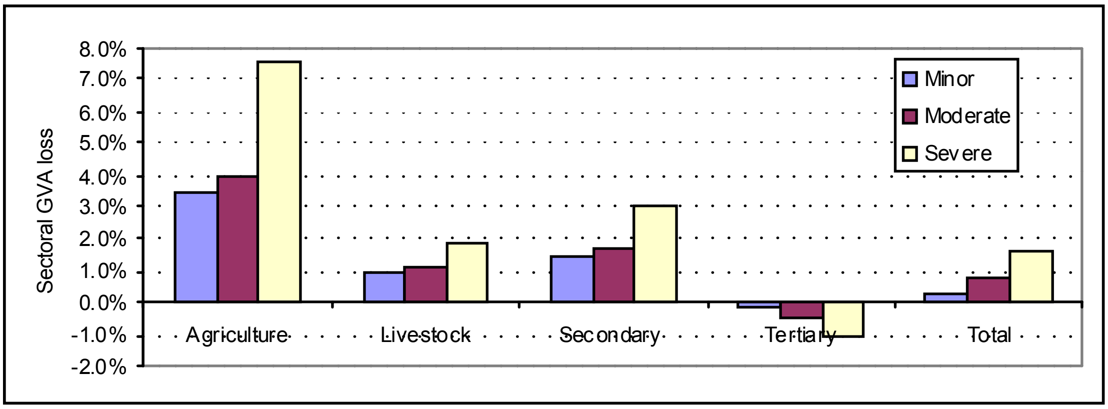
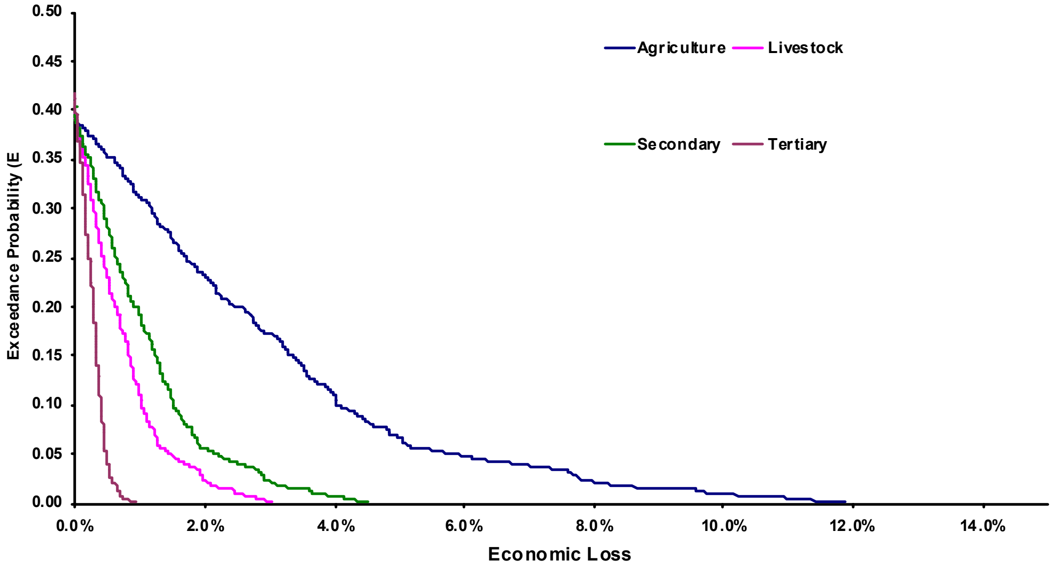


Figure 5.4: Economic Losses, In Sectoral GVA, Caused By Droughts, State Of AP – Exceedance Probability Curve



5.10. The economic impact of drought events can also be captured through the exceedance probability curves, as shown on Figure 5.4. A moderate drought event (occurring one in ten years in the study region) would cause 4 % GVA loss in the agricultural sector, 1.5% GVA loss in the secondary sector, and 1% GVA loss in the livestock sector. In case of severe drought, which is a rare occurrence event, these losses would increase to 7% for the agriculture sector, 3% for the secondary sector, and 2% for the livestock sector. Similarly to the GVA analysis on Figure 5.3, the secondary sector is more exposed to drought due to its inter-dependence with the agriculture sector than the livestock sector.

5.11. Analyses presented in Figures 5.3 and 5.4 show that drought events in the drought-prone region of the eight selected districts mainly affect the state-wide agricultural sector, with modest losses in the livestock sector and the secondary sector. Thus the indirect economic losses outside the agriculture sector appear limited, or may even generate (marginal) gains in the tertiary sector. The total impact on the AP economy, as measured through the loss in total GVA, is marginal. This finding is consistent with a growing body of evidence on the macro-economic impact of climate-related disasters. Based on world-wide historical data, a recent study shows that the maximum impact of drought is 0.8% of GDP for a group of developing countries on an annual basis (Raddatz 2005).

5.12. This analysis focuses on the macro-economic impact of drought in AP. It does not capture the impact of drought on the government's revenue and expenditure, i.e., its fiscal impact. It is worth noting that the state fiscal deficit (total revenue – revenue expenditure – capital outlay – net lending) increased by 7.6% in 2003-04 following the drought year 2002-03. However, several factors contributed to the deterioration of the fiscal performance in the fiscal 2003-04, which was the election year.

5.13. It is useful to compare the state-wide economic impact of drought with that of other climate extremes. Another recent World Bank study focused on cyclones and floods in Andhra Pradesh, using a similar modeling framework as applies to rapid onset disasters (see Box 5.1). Interestingly, the annual average loss caused by droughts on the AP economy (measured in terms of loss in GVA) is lower than that due to cyclones or floods, although any comparison has to be made with caution because losses are not measured in 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 due to 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.

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

Due to the 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 are not included in the study, translating into lower damage estimates than would be expected in practice.

In Andhra Pradesh, the selected perils were cyclones and floods. The average annual loss was estimated at USD 61.2 million for cyclones and USD 21.7 million for floods. The probable maximum loss for a one in one hundred and fifty year event was USD 911 million for cyclones USD 191 million.

Source: Financing Rapid Onset Natural Disaster Losses in India: Risk Management Approach, World Bank report, June 2003.

Simulating the impact of structural changes in the AP economy

5.14. The economic structure of AP has profoundly changed over the last two decades, with a decrease of the primary sector (particularly agriculture) and an increase of the secondary and tertiary sectors. Such a structural change, which is likely to continue in the future, can be interpreted as *a macro-economic drought adaptation strategy*, since the secondary and tertiary sectors are only marginally affected by droughts.

5.15. The impact of the economic structure of AP on its resilience to drought is examined through several scenarios in the macro-econometric model, described by Table 5.1. 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.

Table 5.2: Scenarios on the Structure of the AP Economy

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

5.16. The impact of the structural change on the AP economy is shown on Figure 55 by drought category. Such a macro-economic risk mitigation strategy appears very effective and able to reduce the loss in total GVA by about 3 times in Case 1 to 8 times in Case 2. Loss reductions are similar (proportion-wise) for each drought category. Under severe drought, loss in total GVA would be reduced from 1.6 % for the economy maintaining the current structure of that in Andhra Pradesh today (Case 0) to a mere 0.2 % in Case 2, which is a hypothetical case of an economy that is exposed to the same climate risks in agriculture as AP but roughly approximates the current structure of the economy of Brazil.

Figure 5.5: Loss in Total Gross Value Added (TGVA) Under Different Economic Scenarios by Drought Category

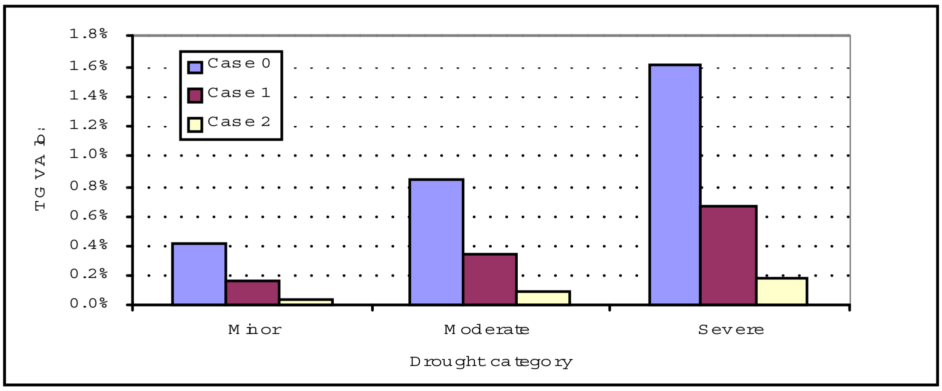
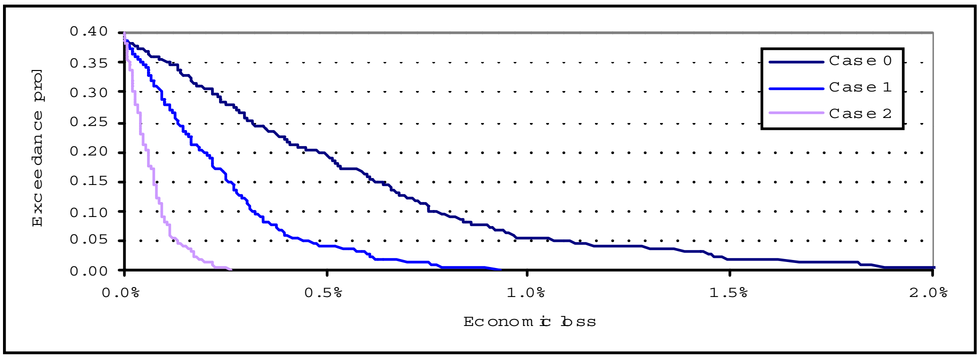


Figure 5.6: Losses in Total Gross Value Added Caused By Droughts Under Different Economic Scenarios – Exceedance Probability



5.17. This message is further reinforced by Figure 5.6. While under current economic structure, there is a chance (of about 5 %) that economic loss (measured in) due to drought will exceed 1 % of total GVA in a particular year, the maximum possible impact due to as major drought is l below 1 % of total GVA in Case 1 and well below 0.5 % in Case 2. Thus, the comparative static analysis shows that the macro-economic impact of drought occurring in the eight most drought prone districts of AP (in terms of loss in total GVA) is quite limited at the state level and that the reduction of the share of the agricultural sector in the total GVA would make this drought impact even smaller.

5.18. However, while the impact of drought, spread over 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. So 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 2002-03 because of the loss in the agricultural value of output is estimated at more than 44 lakhs. This highlights the need for effective strategies that specifically target the most vulnerable to drought economic indicators: output and employment in the agriculture sector, and particularly in the eight most affected districts.

Socio-economic strategies to reduce vulnerability to drought risk: issues and options

5.19. Drought management strategies have been aggressively addressed by the Government of Andhra Pradesh for many years through a variety of programs summarized in Chapter 1 and in Annex 2.[18] The analysis, performed in this study, provides some additional insights on possible options to better adapt to the drought-prone climate and mitigate the adverse socio-economic impacts.

Encouraging alternative employment options in the secondary and tertiary sectors

5.20. Loss of employment is a key concern. The employment situation of a sector gets affected due to the loss in the production. Employment coefficients, obtained from the Input Output table (see Annex 7), provide a measure to account for the loss in employment corresponding to a loss in the production. The agricultural employment coefficient for the state is 5.4, which is rather high relative to other sectors, and confirms the vital importance of the agriculture sector in securing the livelihoods of a large number of people. Interpreting the employment coefficient, a 1 unit fall in the agricultural output will result in a loss of 5.4 employment units. Thus, the employment profile across various sectors has been examined to identify opportunities during drought years

5.21. *Services.* The macro-econometric model estimates that AGVA of last year and TGVA are negatively correlated, that is, a 1% change in agricultural GVA of last year would lead to –0.12% change in the tertiary sector GVA of the current year. This may be partly due to central government transfers through the NCCF, but also maybe to movement of labor from agriculture to services. Bad performance in agriculture may lead to labor moving away from agriculture to certain services; and vice versa. In the service sector, significant employment potential is available in trade and transport (except railways).

5.22. *Construction.* This sector has shown a 49 % increase in the value of output during the severe 2002 drought year. This may be due to increased government expenditure in this sector as a result of the anti-drought poverty alleviation programs, hence providing alternative employment to farmers affected by drought. The construction output multiplier obtained from the I-O is 1.69.[19] Any expenditure in the construction sector will thus lead to the rise in outputs for sectors like cement, steel, bricks and tiles, and additional employment opportunities for the drought-affected people.

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[18] See also "Drought Management Strategies", published by the India Council of Agricultural Research, New Delhi, September 2002.

[19] 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 inter-linkages between the sectors.

5.23. *Other selected sectors.* The sub sectors like fishing, mining and quarrying have shown an increase over the period 1980-81 and 2002-03. An increase is even greater during the drought years. For example, the share of these sectors has increased from 15.9% in 2000-01 to 21.6% in 2002-03. Although these sectors do not have multiplying effect on other sectors unlike construction they have good employment potential. Thus, the labor displaced from the agricultural sector has a potential to be absorbed in the construction, fishing, mining and quarrying sectors, moderating the employment loss in the agricultural sector due to drought.

Supporting structural shift in the primary sector

5.24. *Poultry sector.* During the drought years of 1993-94 and 2002-03, LGVA has increased, although AGVA has decreased in these years. Livestock sector experienced a 77 %rise in the production for the drought year of 2002-03 over 1998-99, 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 has decreased from 55 %to 50 %, while that of meat has remained about the same. Against this backdrop, it is important to note that the value of eggs has shown a rise; the contribution has almost doubled from 8 % to 15 %. The good performance of the poultry sector during drought might have been due to some government interventions, which appeared working. Therefore, there is a case for continuing to encourage the poultry sector (not meat).

5.25. *Cropping pattern.* The VOP of the agricultural sector has decreased by as much as 27% in 2002-03. Particularly, the VOP of rice and groundnut dropped by as much as 38% and 57% (relative to 1998-99) respectively and this greatly impacted the loss of VOP for the total agricultural sector. While the output values of crops like jowar (sorghum), maize and other food grains has shown a rise, 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 in the sate, has outweighed the rise 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.

5.26. Chapter 4 provides a quantitative assessment of reduced production losses form such shift using an example of two drought-prone districts. The Input-Output analysis also points to a potential for some savings in terms of the inputs required for producing these crops; for example, 30 % more input is needed for producing 1 unit of paddy than producing 1 unit of maize. At times of drought the output drops but the inputs for production do not drop in the same proportion. This can be seen by comparing the input proportions for different sectors under agriculture for 1998-99 and 2002-03.

5.27. Therefore, a shift in the cropping pattern from rice to less water intensive crops, particularly in the eight districts in question, is likely to result in both reduced VOP loss and savings in inputs. While this strategy would help reduce the state-wide agricultural GVA loss, its impact would be of particular significance for the farmers operating in these districts. This further emphasizes a conclusion from Chapter 4 about the importance of designing and providing assistance to farmers in a manner that does not simply help absorb the risk of extreme weather events but promotes agricultural and economic practices sustainable in the long-term.

Chapter 6: Conclusions and Recommendations

6.1. This chapter summarizes the key outcomes and conclusions of the study in the three areas, defined by the study objectives: methodology development, analyzing the impact of drought in AP, and assisting the AP government to develop a forward-looking drought adaptation strategy.

Methodology Development

6.2. Catastrophic modeling is still an evolving science which aids policymakers and other stakeholders in managing the risks from natural disasters. The existing models developed by international risk modeling firms focus on the impact of rapid onset disasters, like earthquakes or hurricanes, on public and private infrastructure. These models have been recently 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 different characteristics from rapid onset events that are more difficult to quantify. In particular, they mainly have a direct effect on agricultural output, as well as a variety of indirect impacts. Therefore, an important contribution of this study is in modifying and testing an original model under a different risk assessment paradigm that can be applied to slow onset disasters.

6.3. ***This probabilistic drought risk assessment model offers policy makers a powerful tool*** 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 to capture the underlying uncertainty related to weather events, including the impact of anticipated permanent changes in global climate. The innovative framework developed under this study, which expands 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.

6.4. ***A number of specific areas for model development to increase its practical value, as a planning and decision support tool, has been identified by the study,*** such as:

- *Enhancing model's capability to be applied at a farm level.* This would allow the model to incorporate more realistic behavior of the farmers 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, 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 macro-econometric specifications* on a larger dataset to increase the predictive power of the model.

6.5. ***One more, specialized area for further development and application lays in revisiting agricultural insurance through catastrophe modeling techniques.*** One of the main reasons why crop insurance has so far been almost universally a failure world-wide 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 a highly location, time and crop specific phenomena, with rather confined average losses, which can be further reduced by changing crop and irrigation pattern. The probabilistic drought risk model may thus create new growth opportunities for commercial agricultural (crop) insurance, which until today is almost non-existent.

6.6. ***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 less financially attractive in the short-term).

Findings and observations from the quantitative analysis

6.7. ***The study findings highlight the importance of intensifying efforts to support economic and social development of drought-prone areas that is sustainable and resilient to water-scarce conditions in the long-term.*** Frequent drought is a difficult fact of life 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 % chance (or every 2 to 3 years) that the value of crop production output for the five major crops combined – paddy, maize, jowar (sorghum), sunflower and groundnut - will be somewhat less than in a "normal" rainfall year. Loss of crop production output exceeds 5 % of the "normal" year output value every 3 years, 10 % - every 5 years, 15 % - once in 10 years, and 25% - once in 25 years. The Average Annual Loss (AAL) of output due to the drought-prone climate is at 5 % for the eight district region, ranging form 6 % in the worst affected Anantapur district to 3 % in Prakasam. Individual farmers may suffer greater losses if their particular crops happen to be hard hit. Importantly, for many small and marginal farmers in these districts, a loss of output value of 10% or even 5 % - which is shown to likely happen quite frequently - can mean falling under the poverty line. The bottom line is that, despite a variety of anti-drought programs, the human and social costs of drought have been and remain devastating for millions of people in AP. This suggests the need for enhancing an existing strategy by innovative, forward-looking approaches and tools, to help these people to adapt to frequent droughts.

6.8. ***Impacts of drought are highly variable and localized.*** In addition to large variations across time series, the impacts vary greatly across locations and crops and depending on drought severity. Modeling highlights significant variations for a particular crop across districts and even blocks within the same district. For example, severe drought is likely to reduce rice yields from 29% in Nalgonda to 62 % in Kurnool. 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 mm of rainfall every year. Importantly, different crops can be particularly vulnerable in different districts.

6.9. ***Loses borne by farmers due to drought can be significantly reduced by adjustments in farming practices that reduce water demand,*** such as permanent shift to a larger share of less water intensive crops in the cropping mix. Evidence shows that 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. This is however practiced as a temporary measure with the area of rice typically restored once the drought is over. The model assessed some scenarios of *permanently reallocating water from rice* in order to provide 50 mm irrigation for the four rain-fed crops, included in the model, at one or two critical stages in their growth. In Anantapur, *this strategy is able to 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 changing the cropping pattern, do not appear to have a significant long-term effect on a large scale.

6.10. ***The impacts of measures that can be adopted by farmers are also 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.

6.11. ***Location-specific analyses are needed to inform the development of effective drought adaptation plans for affected areas.*** One of the striking findings of the analysis was a degree of variation in drought impacts on different crops in different locations, clearly suggesting that there is a significant scope for increasing the effectiveness of advice to farmers about undertaking drought coping measures, such as switching to alternative crops in a response to 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 demonstrates 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 analytical capability of the model can be further strenghened as discussed in the model development section above.

6.12. ***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.

6.13. ***The impact of drought on the overall state economy, measured in Gross Value Added (GVA), is marginal and declining.*** Underlying structural changes in the AP economy are the key reason for this effect. The long-term Average Annual Loss in GVA for the state due to all drought events is estimated at 0.2%, even under the benchmark (business as usual) case. During the years of severe drought, an event which happens once in about 30 years in the eight district region, the loss in total GVA rises to 1.6 %. Sector-wise, the macro-econometric 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, and an even positive impact on the tertiary sector. The trend of the AP economy over the last 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 macro-economic impact of drought will further decrease.

6.14. ***Accelerating an observed structural shift in the AP economy from the agriculture sector towards the secondary and particularly tertiary sectors can be interpreted as a powerful macro-economic drought adaptation strategy.*** The impact of such shift on economy's resilience to drought is examined through several scenarios in the macro-econometric model, corresponding to different shares of the agriculture, livestock, secondary and tertiary sectors in total GVA. The analysis has shown that the loss in total GVA due to drought events can be reduced by 80 % (for a scenario when the shares of the agriculture, secondary and tertiary sectors roughly approximate the structure of the economy of Brazil). In the case of severe drought in the eight district region, this means that the loss in total GVA can be reduced from 1.6% to 0.2%. These encouraging signs in the average macro-level indicators provide an opportunity for the state to more actively and effectively provide targeted assistance to those whose life and well-being are devastated by drought.

6.15. ***The above findings are consistent with a growing body of evidence on the macro-economic impact of climate-related disasters.*** As a devastating one time event as it is, the macro-economic impact averaged over time and/or space is usually small. Based on world-wide historical data, a recent study shows that the maximum annual impact of drought is 0.8% of GDP for developing countries as a group. Furthermore, the state-wide economic impact of drought in AP was compared with that of cyclones and floods. The impact of those was assessed by another recent World Bank study that used a similar modeling framework as applies to rapid onset disasters. The annual average loss caused by droughts on the AP economy is lower than that due to cyclones or floods, although any comparison has to be made with caution because losses are not measured in the same unit (loss in GVA for droughts, and loss in public infrastructure and housing for cyclones and floods).

6.16. ***The analysis gives additional useful insights on the impact of drought on different sectors that can inform government policies.*** Interestingly, the livestock sector is less affected by drought than the secondary sector, due to the inter-dependence of the latter with the agriculture sector. Thus, the future impact of drought on the rural economy can be also moderated due to an increasing role of the livestock sector. This is consistent with the analysis of historical data on past droughts which reveals a declining trend impact on both the overall economy and the primary sector. Furthermore, the macro-econometric model estimates some gains for the tertiary sector (with one year lag) as a result of future droughts. Several factors may account for the boost to tertiary sector production: central government transfers, changes in consumption patterns caused by the drought and an increased supply of labor.

6.17. ***Optimistic outlook based on aggregated data should not take attention away from immediate problems related to drought vulnerability.*** Droughts have had and continue to have a negative impact on the performance of the agriculture sector and, thus, the lives of the millions of the rural poor. A range of these impacts is painfully clear from a survey of communities in one of the poorest and worst affected districts, Mahbubnagar, undertaken by another study. While some farmers/households are able to change the farming decisions or migrate to other sectors, the others are left with extreme responses including starvation, loss of health, and even suicide. These responses reinforce the conclusions from the analysis that the impacts of drought are highly differentiated, and require tailored assistance to those in need.

6.18. ***Furthermore, 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, rather high relative to other sectors, and implies a 1 unit loss in output will result in more than 5 units of employment loss. So any external shock to the agricultural sector has a strong impact on employment. The total employment loss for 2002-03 linked to the loss in the agricultural output due to a major drought is estimated at more than 44 lakhs. This highlights the need for strategies that specifically target the most affected by drought economic indicators: output and employment in the agriculture sector, and particularly in the most vulnerable districts, mandals and communities.

6.19. ***Several opportunities are identified outside the agriculture sector to mitigate the impacts of drought on employment and income in the short-to- medium term.*** The analysis of the extensive economic data collected and generated by the study indicates a number of opportunities outside the agriculture sector which could be particularly effective for mitigating the impact of drought. The options that arise from the analysis are: (i) in the service sector, significant employment potential is available in trade and transport (except railways); (ii) investment in the construction sector will increase employment in this and related (cement, bricks, steel) industry; (iii) the labor displaced from the agricultural sector also has a potential to be absorbed in the mining and quarrying sectors, moderating the employment loss in the agricultural sector due to drought; and (iv) the poultry sector (rather than meat) appears to have a good drought risk mitigation potential in 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.

Areas for Future Action

6.20. ***Need for a multi-tiered strategy combining economy-wide and sectoral policies with well targeted efforts at the micro-level.*** Drought is a complex and challenging natural phenomenon. It is even more complex and challenging socio-economic phenomenon, with diverse, sometimes conflicting, impacts on the micro, sectoral and macro levels. The analysis reveals stark contrasts through which drought manifests itself – at different geographic levels, on different economic indicators, on different crops and sectors, on different population groups, on different measures of human well-being. Thus, an effective strategy to tackle this phenomenon needs 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 better-off farmers and households are typically better able to use alterative opportunities, including temporarily changing farming practices or migrating to other sectors, whereas the poorer are least resilient to shocks. While far from being exhaustive, this study highlights some elements of a possible strategy for increasing resilience to drought through adaptation at different levels.

6.21. ***At the macro level, continue and accelerate the on-going changes in the economic structure*** that 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 the poultry sector*, as an important buffer to absorb the drought impacts on rural economy;
- *Encouraging shift in cropping pattern from rice to less water intensive crops* to reduce vulnerability to drought impacts (including revisiting and addressing perverse incentives associated with current agricultural input subsides and rice procurement prices).

6.22. In addition, investments (including public investments where appropriate) 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 sub-sectors – can be used to moderate the impact of drought on affected communities in the short to medium term.

6.23. ***The key is to address a growing gap between the encouraging macro-economic trends and the impacts on farmers and communities in drought prone areas***, as highlighted by the analysis. The state-wise 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 opportunity due to drought.

Thus, it appears critical to intensify on-going efforts and initiatives as to promote more effective, targeted and coordinated assistance to those in greatest need.

6.24. ***Initiate development and implementation of drought adaptation plans for the most affected areas at the mandal/district level.*** At the center of these plans will be measures that promote a gradual shift to more sustainable agricultural practices (e.g. changing cropping pattern in favor of less water intensive crops) and other economic activities that are less vulnerable to drought (e.g., livestock, agro-industry), 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 attainments of affected communities. The planning process, aimed to help communities develop a broadly shared and owned strategy for securing stable and sustainable sources of income and livelihood, ought to involve participatory, community-driven approaches. This initiative should build on the existing successful experiences with community-based watershed management in AP, as well as integrate relevant schemes by different departments to the extent possible.

6.25. ***Create a supporting institutional and policy framework.*** This planning and implementation process would require commitment and involvement by all levels of government - from 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 start-up costs of transition to different crop, technologies and economic activities.

6.26. ***Explore innovative micro-financing/insurance schemes for farmers that promote 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, rainfall insurance schemes have been offered by private insurance companies on a pilot basis since 2003. While such innovative risk financing arrangements offer farmers new opportunity to finance their losses, it is however important to ensure that they do not perpetuate the current situation of heavy farmers' dependency on rainfall. A sizable average crop output loss due 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.

6.27. ***Specifically, two lines of possible innovative financing products are proposed by the study:***

- *Drought adaptation insurance* could provide coverage against risks due to a shift from non-viable farming business to viable (agricultural and non-agricultural) business. This insurance product would thus protect farmers against new sources of risks resulting from a change in their farming practices that are more drought-resilient and less water intensive.

- *Drought adaptation credit* could provide initial capital to shift to 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.

6.28. ***Develop Decision Support Toolkit for drought management planning.*** A drought risk model developed by this study, complemented by other tools and methods (such as a real-life drought forecasting system developed by CRIDA), could provide a good scientific and information basis for supporting drought adaptation and management planning at the block level.

6.29. ***Facilitate informed public debate on drought adaptation strategies by assessing and disseminating information on the impacts and various options.*** The modeling and analysis conducted in this study indicate that it is possible to test, quantify and conduct an objective assessment of economic losses caused by drought. This model, however, is only one contribution into a rich body of work on drought undertaken in India and elsewhere. This information needs to be more effectively disseminated to all the concerned stakeholders to assist with developing a common vision and reaching broad-based agreement on the program of action.

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