Vulnerability and Adaptation to Drought: Economic Impact Scenarios*

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April 26, 2017

For Drought Mitigation and Preparedness Workshop, Washington DC

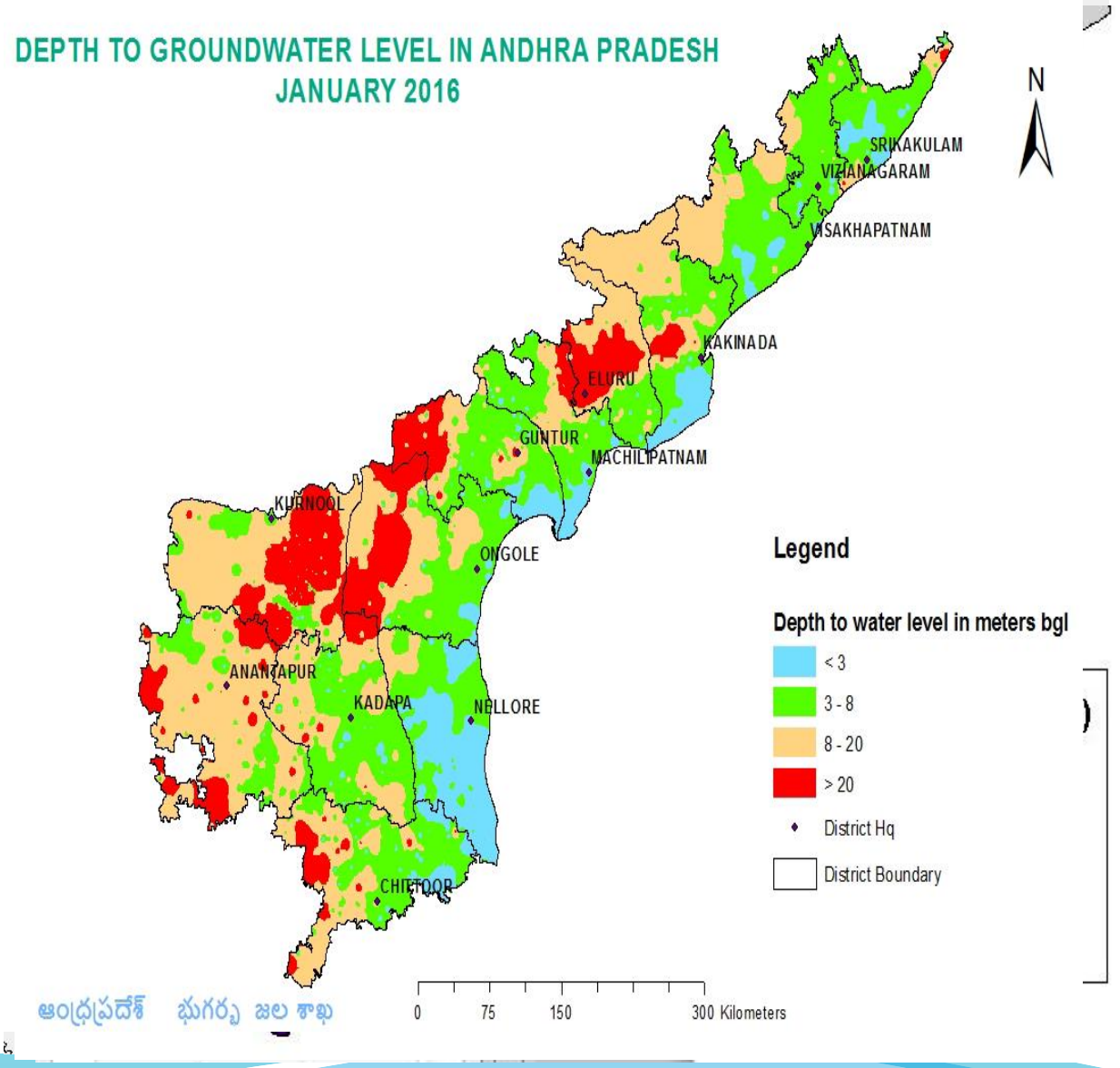
*https://openknowledge.worldbank.org/handle/10986/11703

Objectives – Outline of the Presentation

- Drought and Economy Perspective: AP Case Study
- Methodological Framework
- Analyzing Vulnerability to Drought
- Economic Impact of Drought
- Conclusions

Case Study : Erstwhile Andhra Pradesh

- Telangana (9 districts)
  - Three districts (Rangareddi; M'nagar and Nalgonda)
- Andhra Pradesh (13 districts)
  - Four districts in Rayalaseema region (Anantpur; Chittoor, Cuddapah and Kurnool)
- Study Scope (8/23 districts)
- Rain shadow districts
  - Groundwater based economy
  - Home to 35% (30M) of total population
  - Majority (70%) is dependent on agriculture



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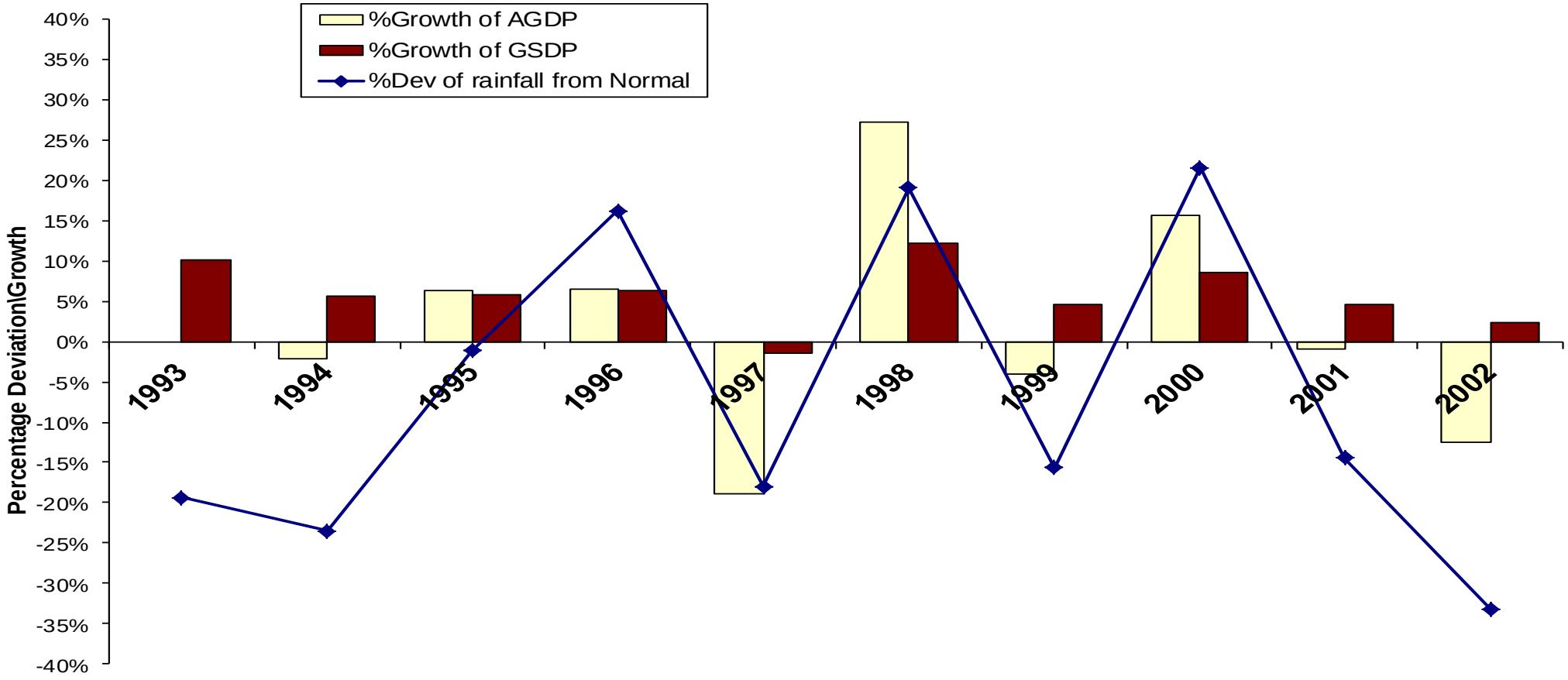
Drought and Economic Perspective

Rainfall and economic performance in Andhra Pradesh



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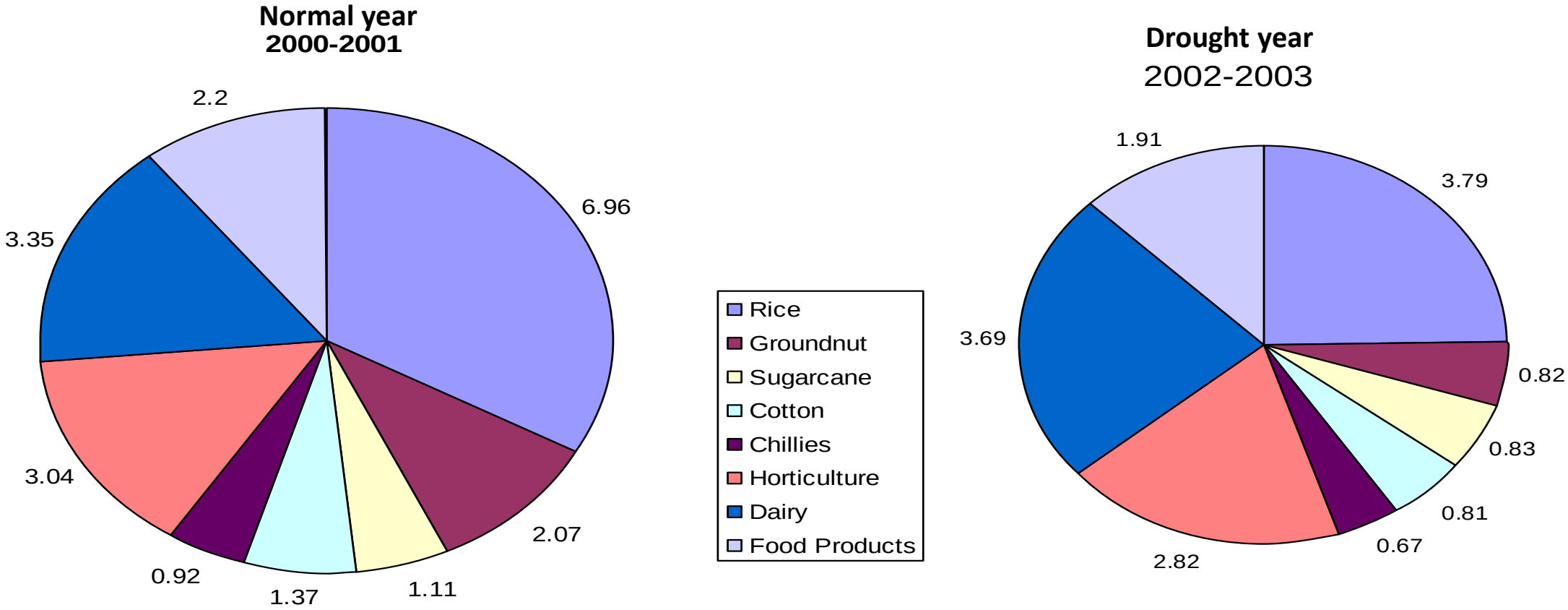
2002 Drought Effect on Agriculture

- 2002 drought on agriculture and its contribution to GSDP



Total contribution of 21.02% in Gross State Domestic Product

Total contribution of 15.34% in Gross State Domestic Product

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Study Rationale

- Develop a framework for simulating long-term impacts of drought in drought-prone areas and at state levels;
- Conduct risk assessments of the impacts under different scenarios; and
- Assist the GoAP in development of a strategy for adapting to drought and water deficits

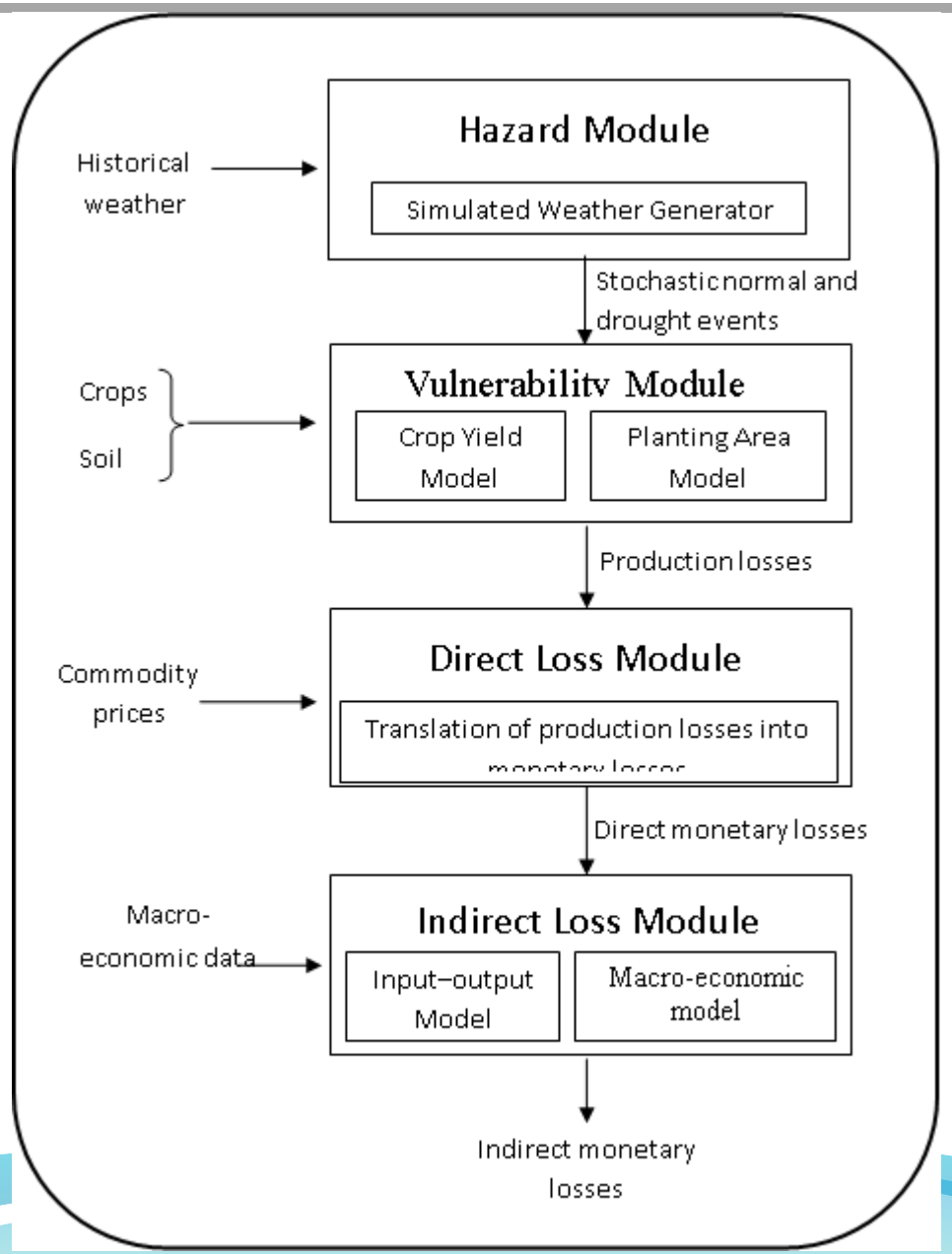
Outputs and Deliverables

- Outputs (EP curve, average annual, return period)
  - Direct losses
    - Agriculture production, value
  - Economic losses
    - GVA, GDP
  - Fiscal losses
    - Revenue, expenditure
  - Drought maps
    - Hazard based on index
    - Risk based on yield/production loss
- Deliverables
  - Report/Publication

Probabilistic Drought Risk Assessment Model

- **Hazard and Vulnerability Module**
  - Mandal/Block level rainfall data used
  - Generated stochastic rainfall events
  - To identify drought events
- Vulnerability : **EPIC*** simulated yield
  - Generated at block level; averaged for district
  - Management inputs taken from ANGRAU
- Observed/reported yield
  - Comparison between simulated & reported
  - For example:
    - 1997, 2002 drought years
    - 1996, 1998 normal years
    - Anantapur and Mahboobnagar

***EPIC: Crop Growth Simulation Model**



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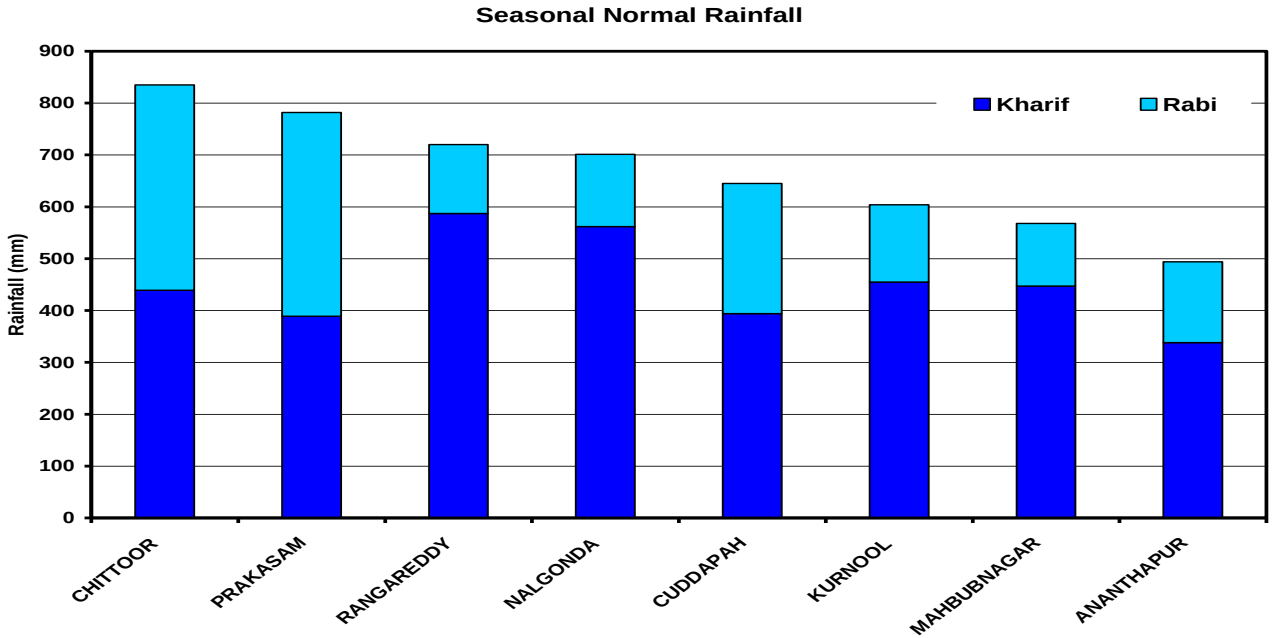
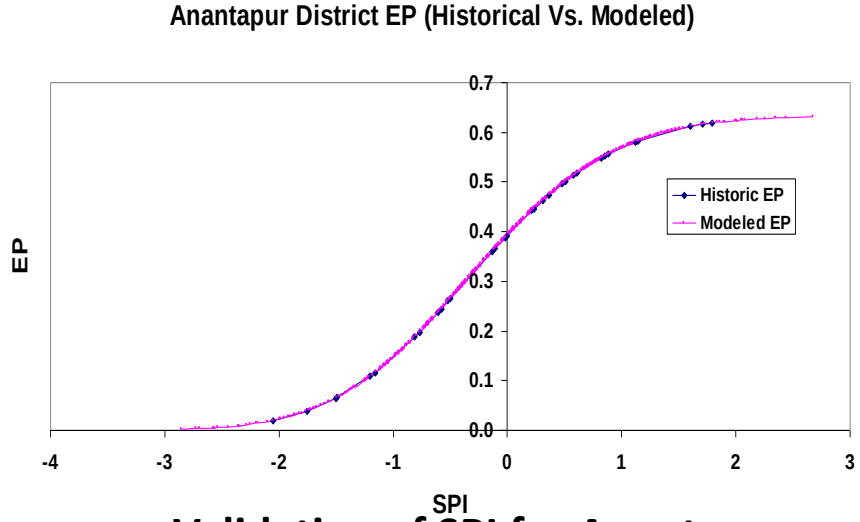
Hazard: Simulation of Drought Events





- **Standardized Precipitation Index (SPI)** is one of the means used fc defining and monitoring drought.
- Its an index based on the probability of precipitation for any time scale.
- It determines the rarity and severity of a drought at a given time scale
- Advantages: developed for any regions/temporal/spatial

Validation of SPI for Anantapur

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

Simulated Return Periods (in Years); however, it defers at block level

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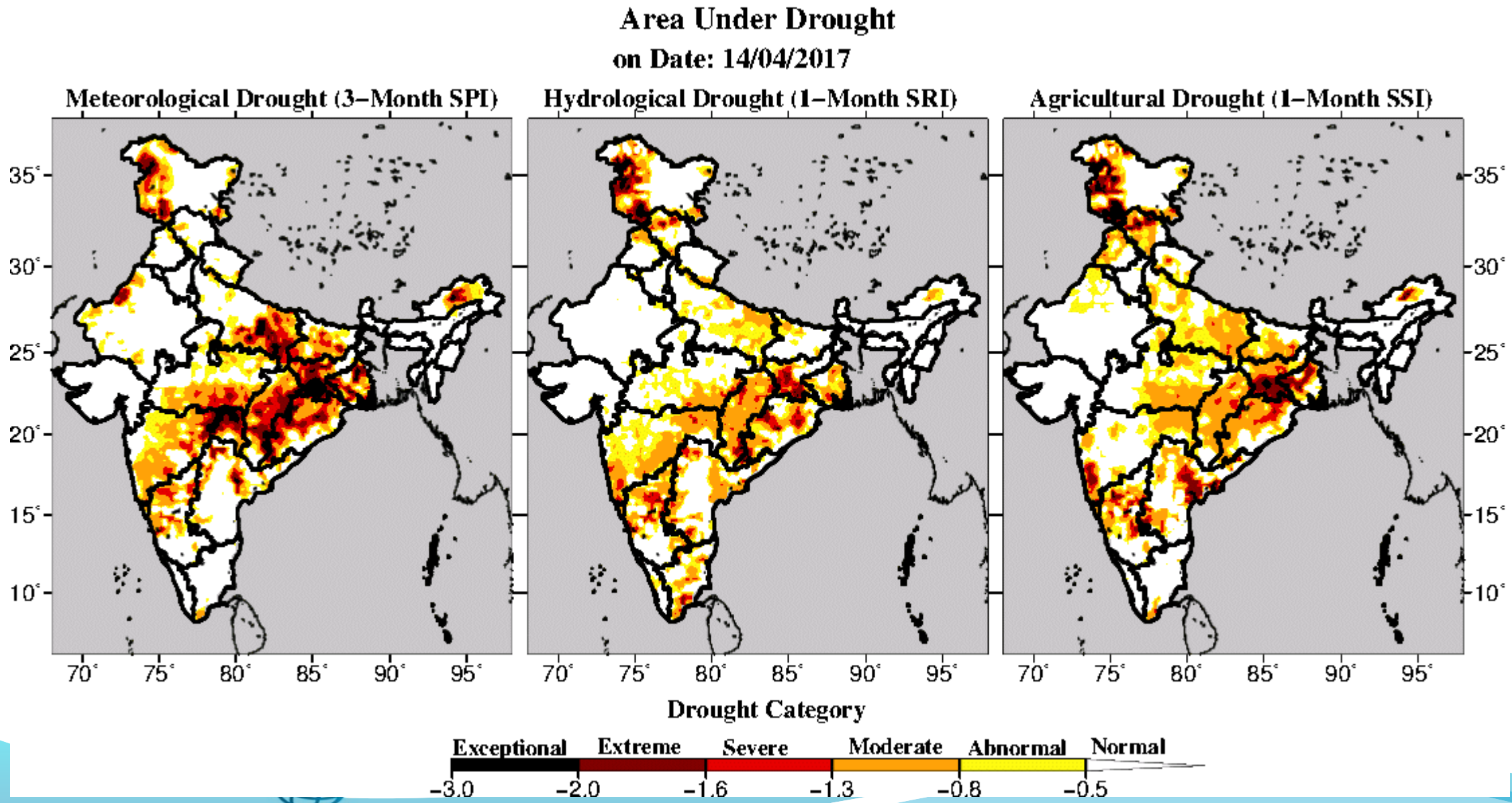
Note: Model simulations based on historical data.

Review of near real time Drought scenario



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Source: https://sites.google.com/a/iitgn.ac.in/india_drought_monitor/home

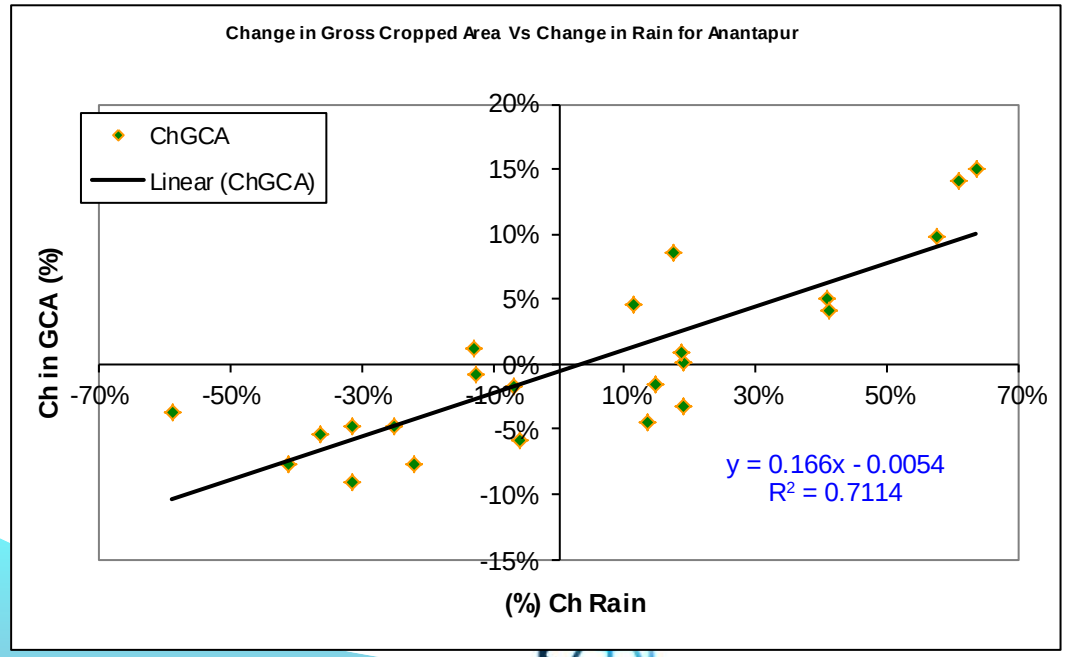
Exposure and Vulnerability Module

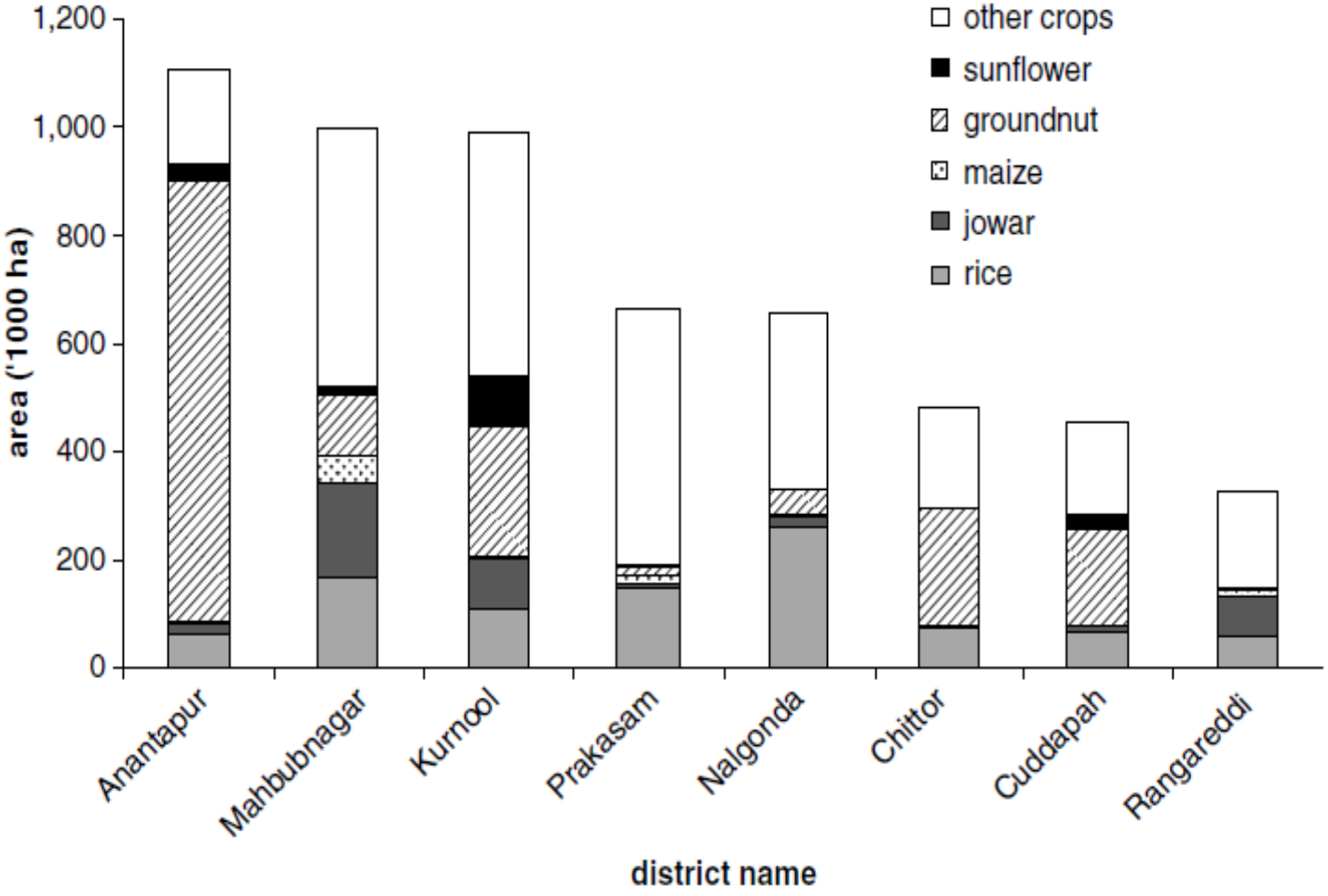
- The average yield and planting area (resolution: block/mandal level)
  - ✓each of the simulated events
- The average yield of five crops (JO, MA, GN, SU, and RI)
  - ✓For category of drought is determined with the help of EPIC model.
- EPIC runs are made at block/mandal level for
  - ✓selected events (10 numbers) representing different categories of drought.
- The events are selected from the 500-year event set
  - ✓for every block to represent each of the drought categories
  - ✓based on a representative SPI value.

Exposure: Computation of yields and production at district level

Planting Area Model:

- GCA, GIA, GrfA versus current year monsoon strike date
- Change in GCA, GIA, and GrfA over previous year with change in rainfall over previous year.





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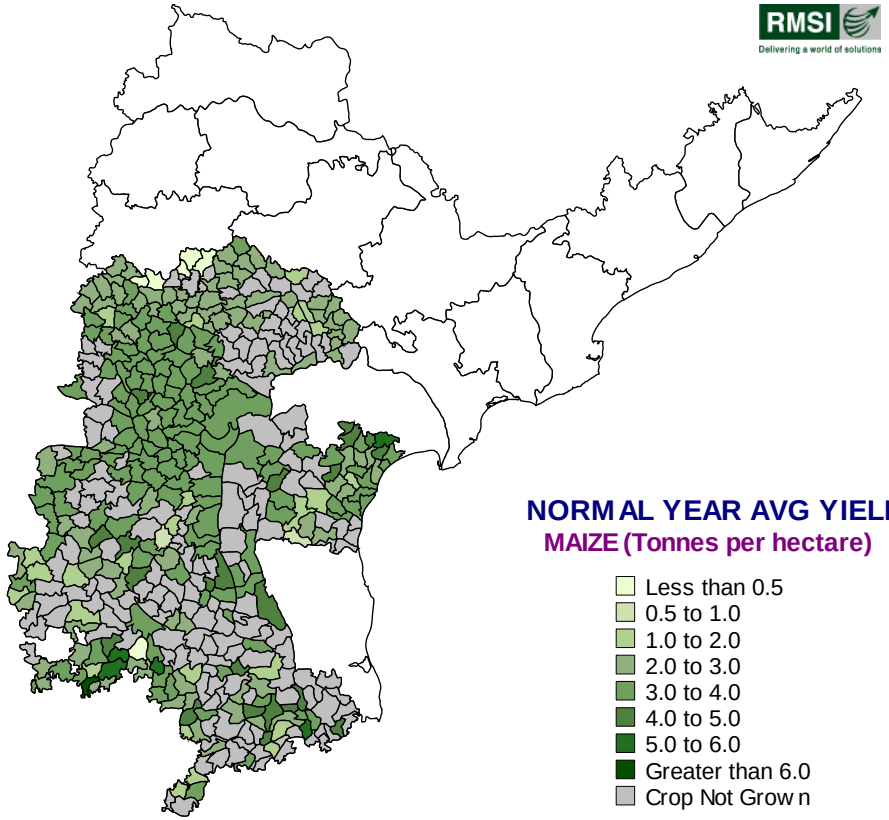
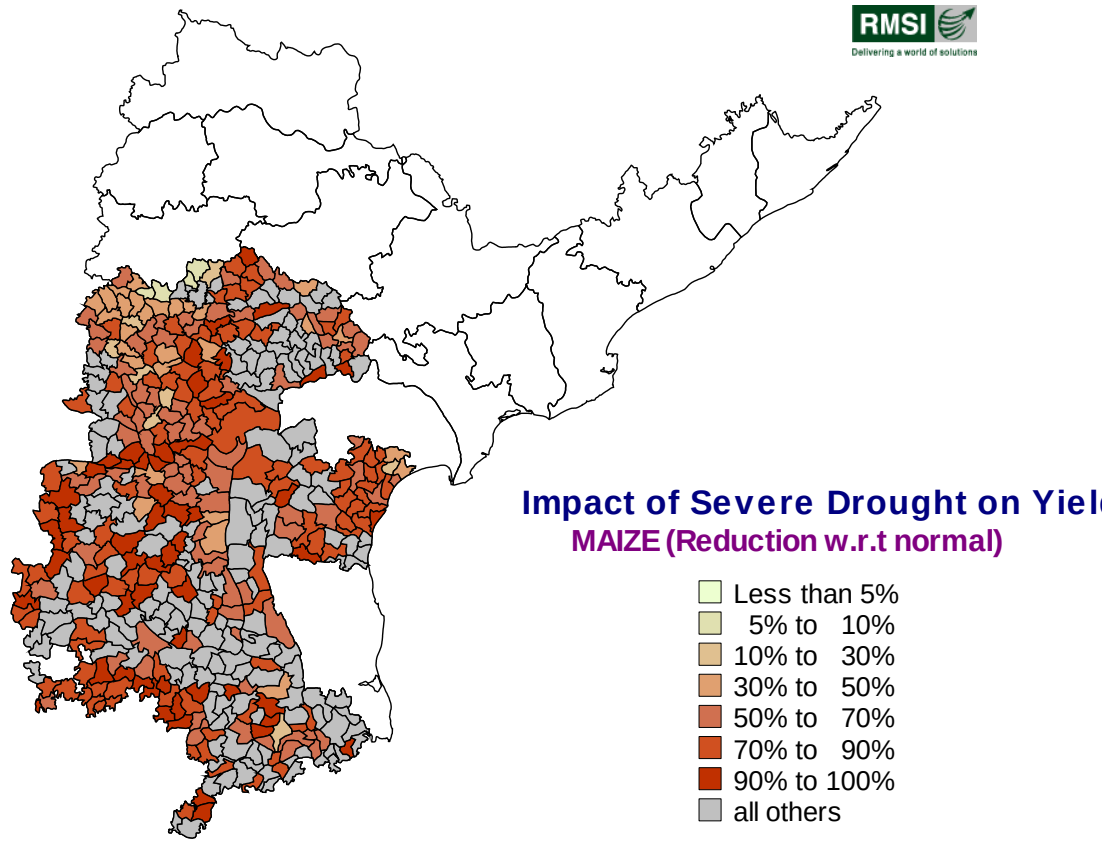
Exposure and Vulnerability Module (2)

Impact of Severe Drought on Yield (% Decrease with Respect to Normal Yield)





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Loss module : Crop-wise loss in production

Production associated with the categories of drought at the block, district and combined levels.

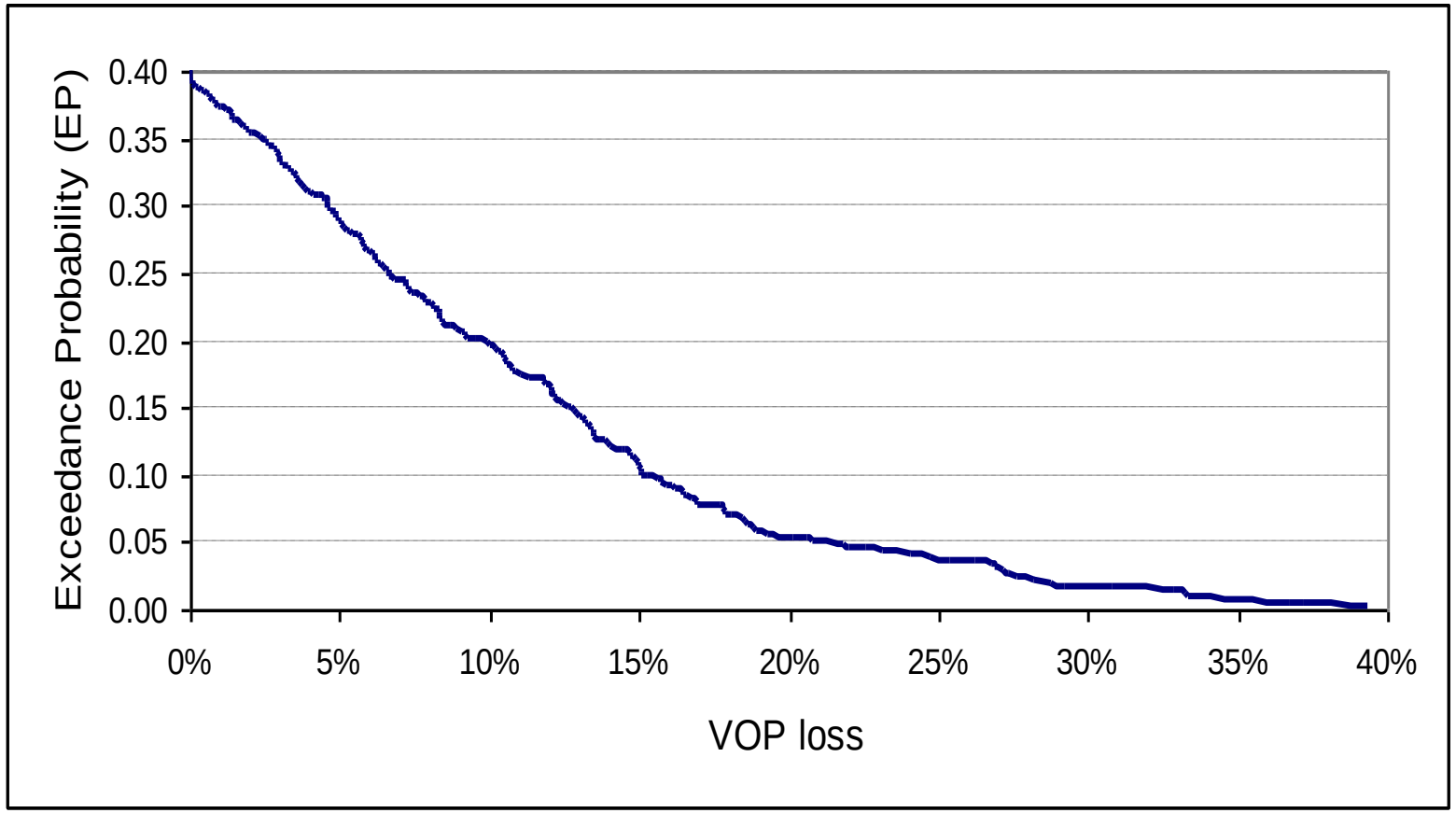
- Production is computed for each of the 500 events at the block-level as
  - Production=Planted area x Average yield.
  - Block-level production is then summed up
  - Events categorized as normal year in the 500-year event set at the corresponding (district or state) level.
- % loss in production for each event and crop is then calculated as:
  - % Loss in Production=100 x (Average Normal Year Production – Production for the event) / Average Normal Year Production

	Anantapur	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%

Rice Yields in Normal Years and Yield Losses in Drought Years

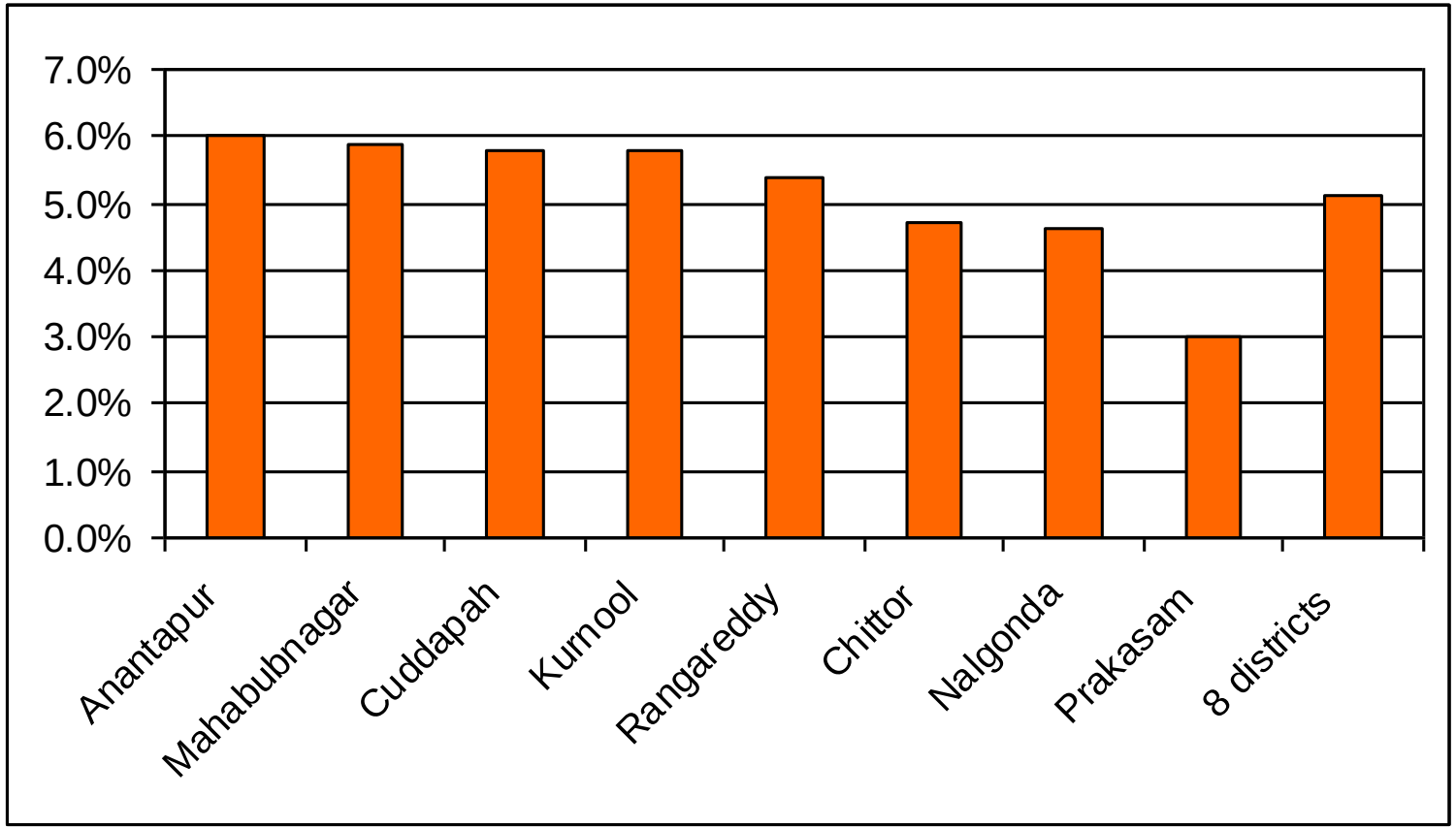
Crop Production Losses Caused by Drought - EP Curve

- Loss of VOP of the eight drought-prone districts is defined as
  - the difference between the VOP of the five crops during a normal year and the VOP during a drought year.
  - the eight districts faced 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



Crop Production Losses Caused by Drought - AAL

- The AAL of output due to exposure to drought
  - 5% (signifcant loss) assuming no changes in the current cropping pattern.
  - The AAL - 6 % in the worst affected Anantapur, followed by Mahabubnagar, and others
- There were further variations within districts, and across blocks.
- For small and marginal farmers, even a 10% or 5% decrease in output could mean falling below the poverty line.



Average Annual Loss of Value of Production Output, by District

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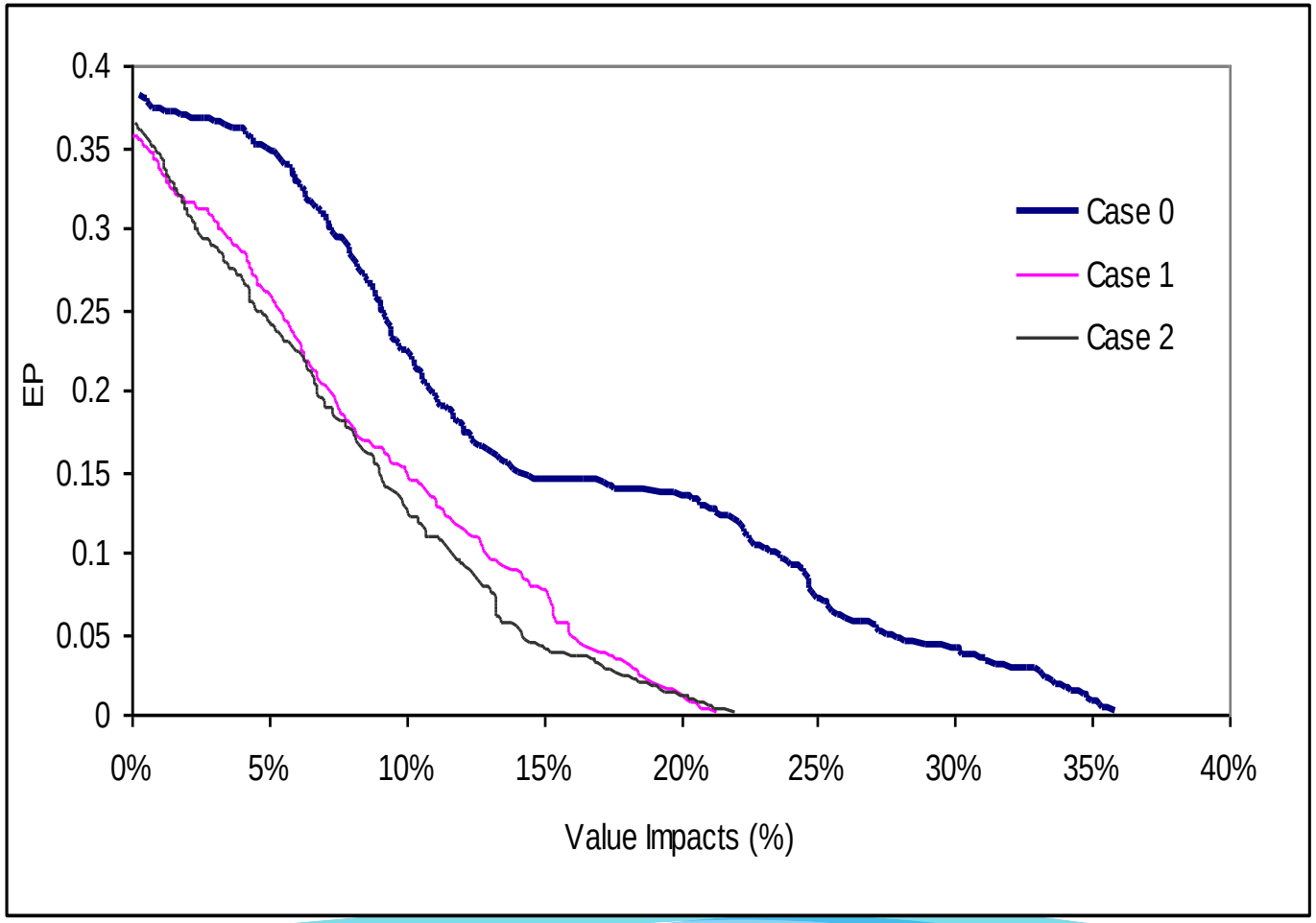
Adaptation Strategies at the Farm Level (1)

Reducing Cultivable Rice Area in Anantapur: VoP Loss Exceedance Probability Curve

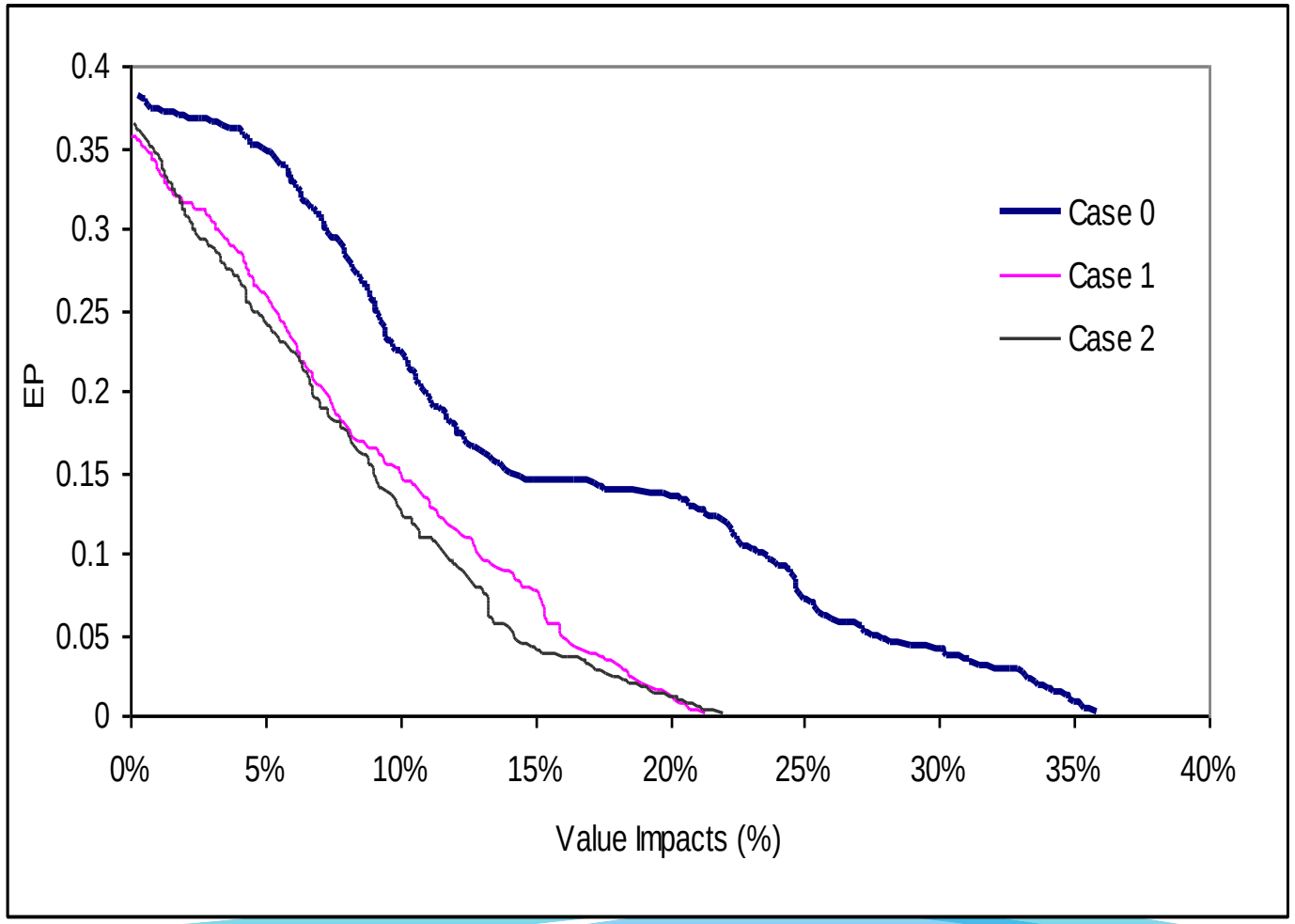
- Case 0 - a typical “real-life” situation during the years of normal rainfall or minor drought.
- Case 1 - single irrigation of rain-fed crops at the flowering stage or its equivalent
- Case 2 - first irrigation as above plus second irrigation at the time of yield (grain formation).



Adaptation Strategies at the Farm Level (2)

Reducing Cultivable Rice Area in Anantapur: VoP Loss Exceedance Probability Curve

- The AAL gain was estimated at 32% under the single irrigation (Case 1)
- AAL gain was 47% under the double irrigation (Case 2)
- Partially reallocating water from rice cultivation to life-saving irrigation to less water-intensive crops would *reduce by half the AAL* during the drought years
- Thus *increase the all-year average annual crop production value* by one-third for single irrigation and by almost half for double irrigation.



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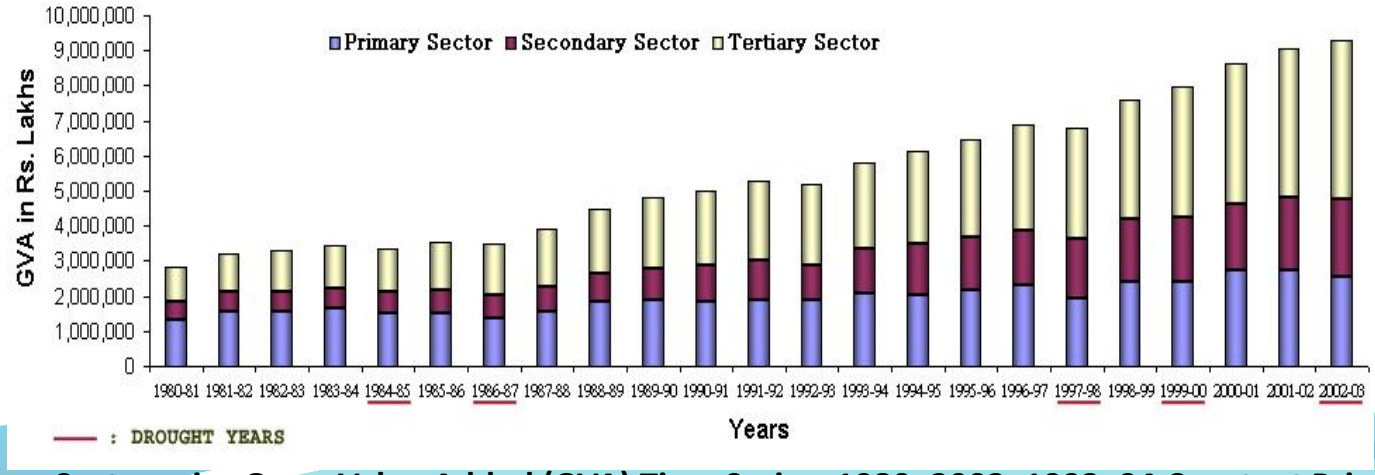
Economic Assessment: Structure of AP Economy

- Structure defined
  - in terms of gross value added (GVA)
  - in various sectors and
  - Interrelations among them
- Primary sector
  - Agriculture, livestock, forestry, fishing, mining
- Secondary sector
  - Manufacturing, electricity, water supply, construction
- Tertiary sector
  - Trade, real estate, railways, communication, banking, public admin, transport, other services

Percentage Changes in AGVA and LVGA, 1993–94 Constant Prices



Sector-wise Gross Value Added (GVA) Time Series, 1980–2003, 1993–94 Constant Prices

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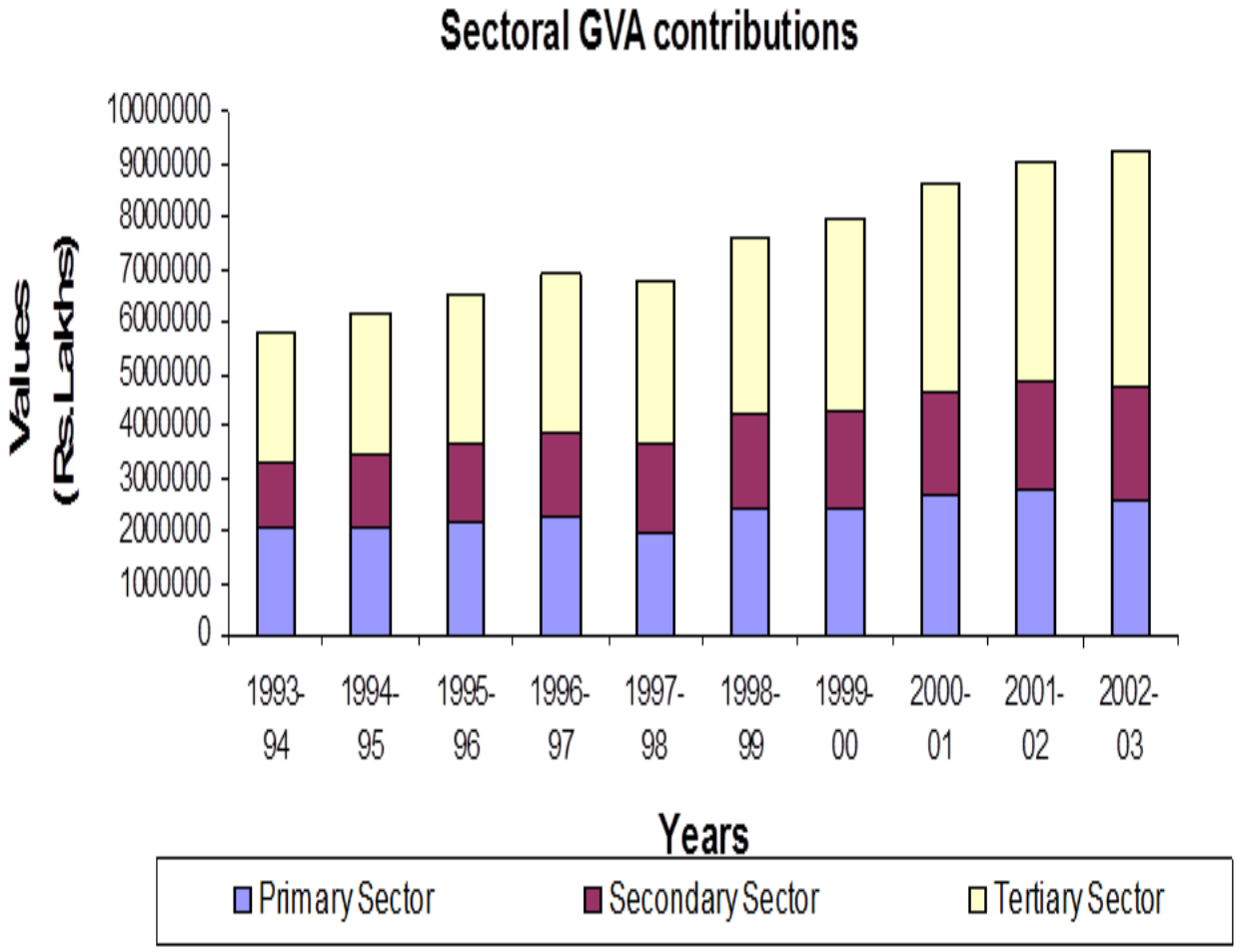
Economic Assessment: Background Data

- Method: Seemingly unrelated regression (SUR)
- Model preliminary specification

Macro Model: Specification

- $\ell n\ PGVA_t = 11.45 + 0.40\ \ell n\ PCFC_t + 0.72\ \ell n\ YIELD_t$ $(R^2 = 0.97)$
- $\ell n\ SGVA_t = 0.71\ \ell n\ SCFC_t + 0.37\ \ell n\ AGVA_{t-1}$ $(R^2 = 0.84)$
- $\ell n\ TGVA_t = 1.33\ \ell n\ TCFC_t - 0.12\ \ell n\ AGVA_{t-1}$ $(R^2 = 0.98)$
  - ‘ℓn’ means natural logarithm
  - $PGVA_t$, $SGVA_t$ and $TGVA_t$ mean primary, secondary and tertiary sectors’ gross value added(GVA), in
    - year t, respectively
  - $AGVA_{t-1}$ means last year’s agricultural GVA
  - $PCFC_t$, $SCFC_t$ and $TCFC_t$ mean the consumption of fixed capital(CFC), in year t, in the primary,
    - secondary and tertiary sectors, respectively.
  - $YIELD_t$ is the agricultural yield in year t



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Economic Assessment: Input-Output Model

- All India I-O table available for 1998-99
- AP I-O table prepared from the all India table
- AP I-O table aggregated from 115 sectors to 19 sectors
- The Final Demand considered (PFCE,Exp/Imp)
- Output multipliers estimated
- Employment coefficients estimated

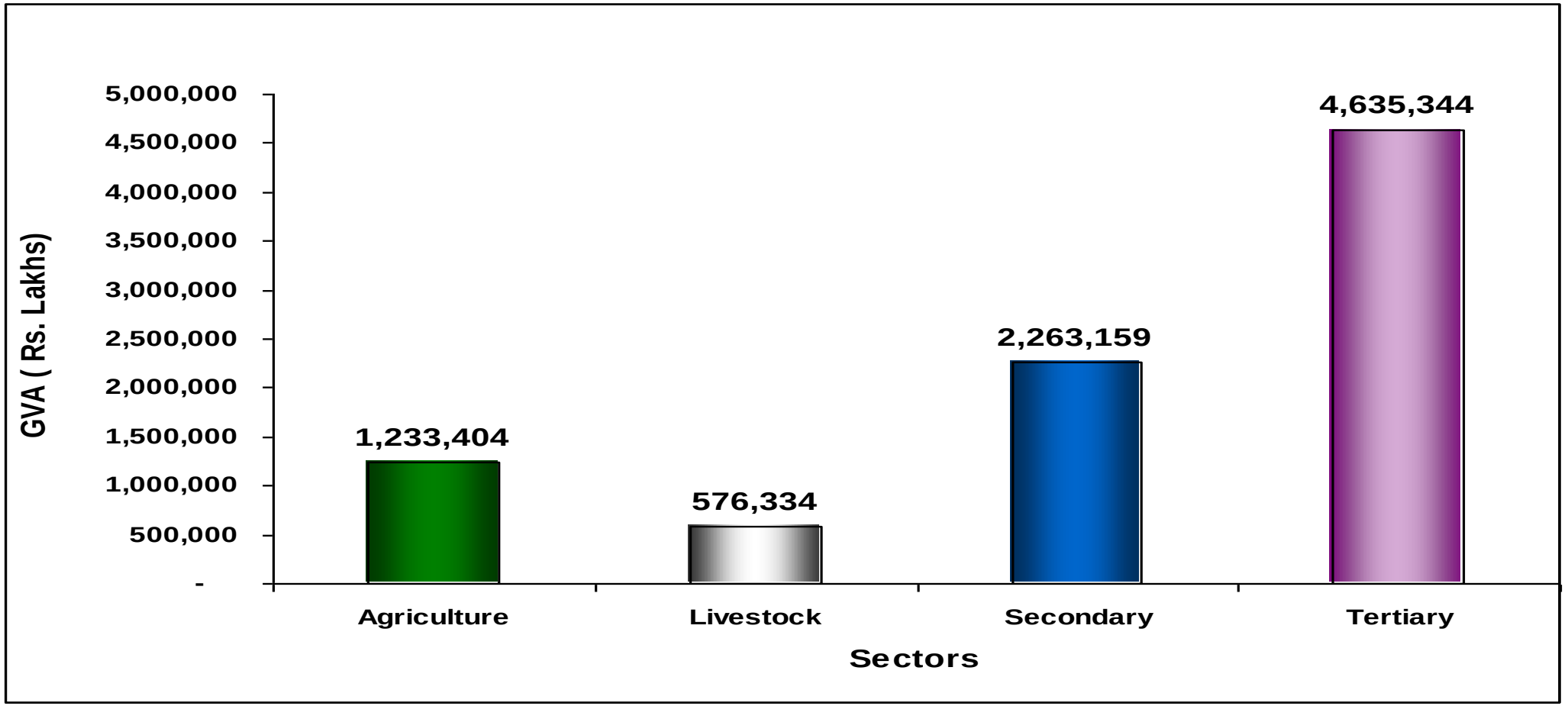
Employment Multiplier

- Employment coefficients
  - Provides the number of workers required to produce Rs.1 lakh value of output
  - For example, to produce Rs. 1 lakh value of agricultural output 7.3 workers are required
- Employment coefficients will be used to calculate employment multipliers
  - It measures the total change in employment in the economy for a unit change in employment in a particular sector.

Commodity	Employment Coefficients
Agriculture	7.31
L & F & L	0.28
M & Q	0.47
Food Products	1.00
MAN (1)	2.59
MAN (2)	0.14
Construction	0.86
EGW	0.08
Railway transport services	0.32
Ser (1)	0.99
B & I	0.15
SER (2)	0.85

Economic Impact of Drought at the State Level

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



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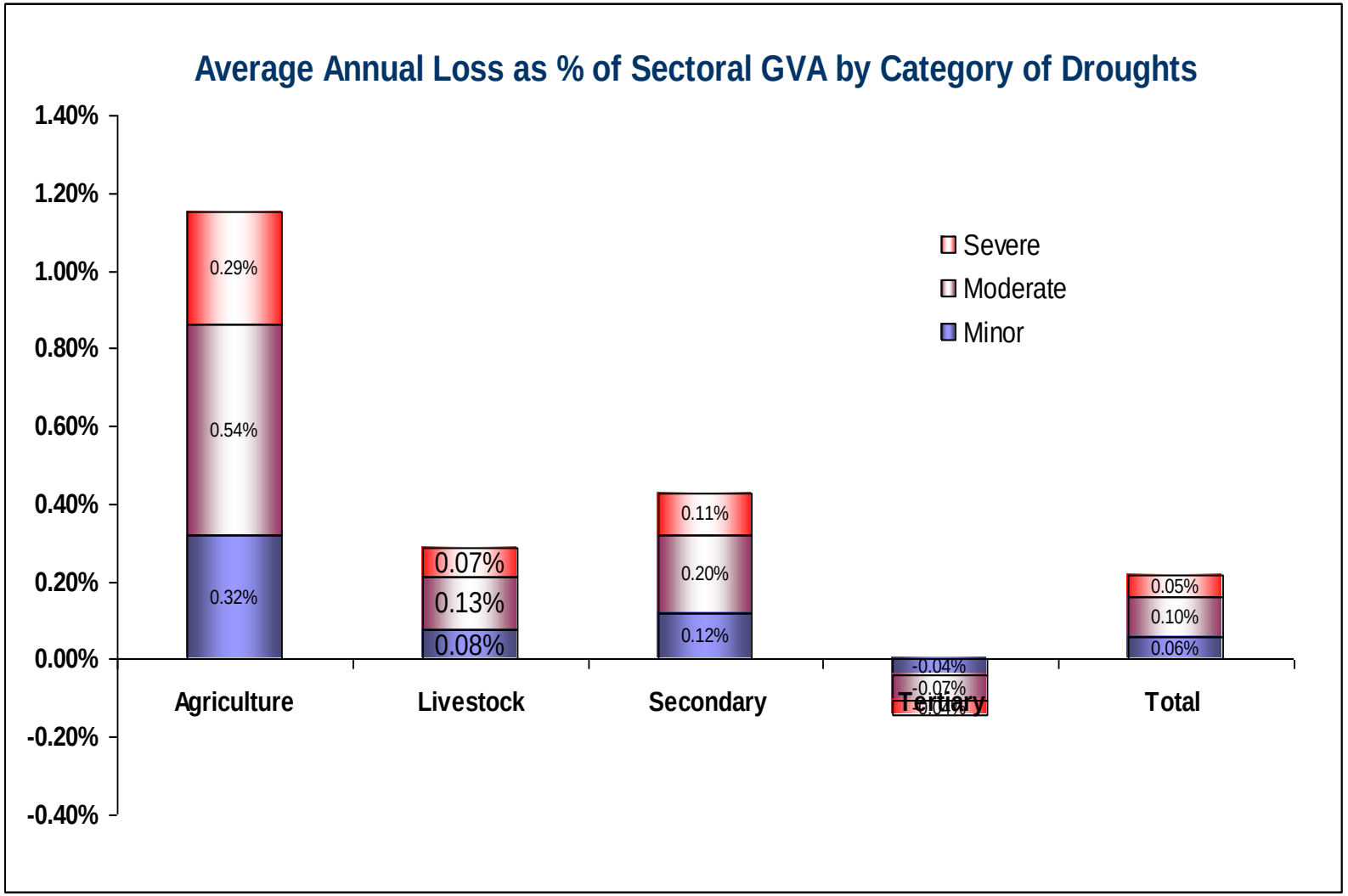
Sector-wise Gross Value Added (GVA) Time Series, 1980–2003, 1993–94 Constant Prices

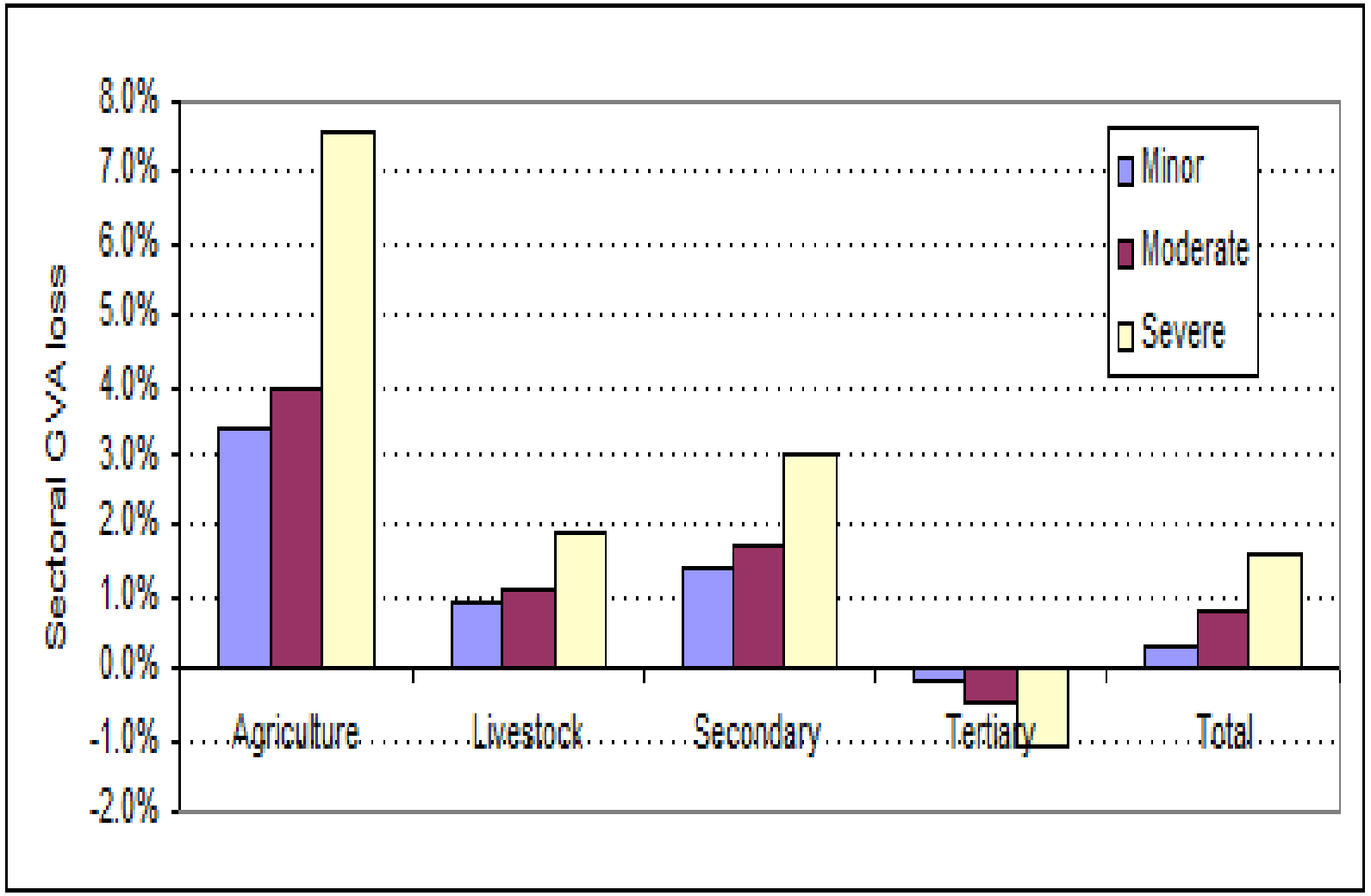
Average Annual Loss as % of Gross Value Added due to Droughts

- 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



Conditional Average Loss in GVA by Sector and Drought Category

- In a minor drought, average loss is estimated
  - > 3% of agriculture GVA
  - < 1% of livestock GVA.
- In moderate drought:
  - ~ 4% of agriculture GVA
  - ~ 1% of total GVA.
- During severe drought,
  - 8% in the agricultural sector
  - 2% for the whole economy;
- Tertiary sector, however, showed a gain of 2%



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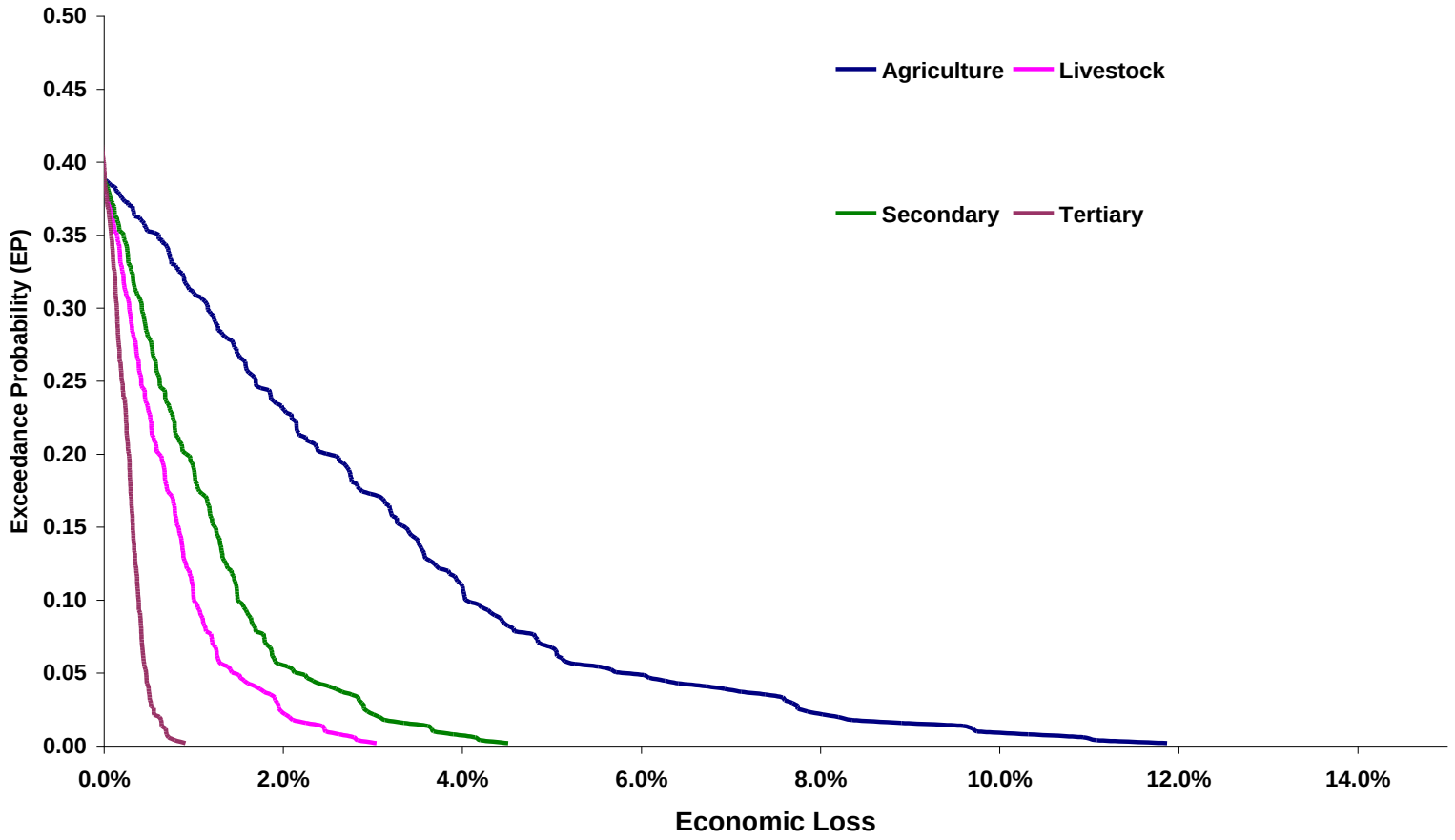
Sector-wise Gross Value Added (GVA) Time Series, 1980–2003, 1993–94 Constant Prices

Economic Losses, in Sectoral GVA, Caused by Droughts - EP Curve

- **A moderate drought event (occurring 1-in-10 years) cause:**
  - **4% GVA loss in the agricultural sector,**
  - **1.5% GVA loss in the secondary sector, and**
  - **1% GVA loss in the livestock sector.**
- **During severe drought,**
  - **increase to 7% for the agriculture sector,**
  - **3% for the secondary sector, and**
  - **2% for the livestock sector.**
- Per GVA analysis shown
  - **secondary sector is more exposed to drought due to its inter-dependence on the agriculture sector than the livestock sector**



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Simulating the Impact of Structural Changes in the AP Economy (1)

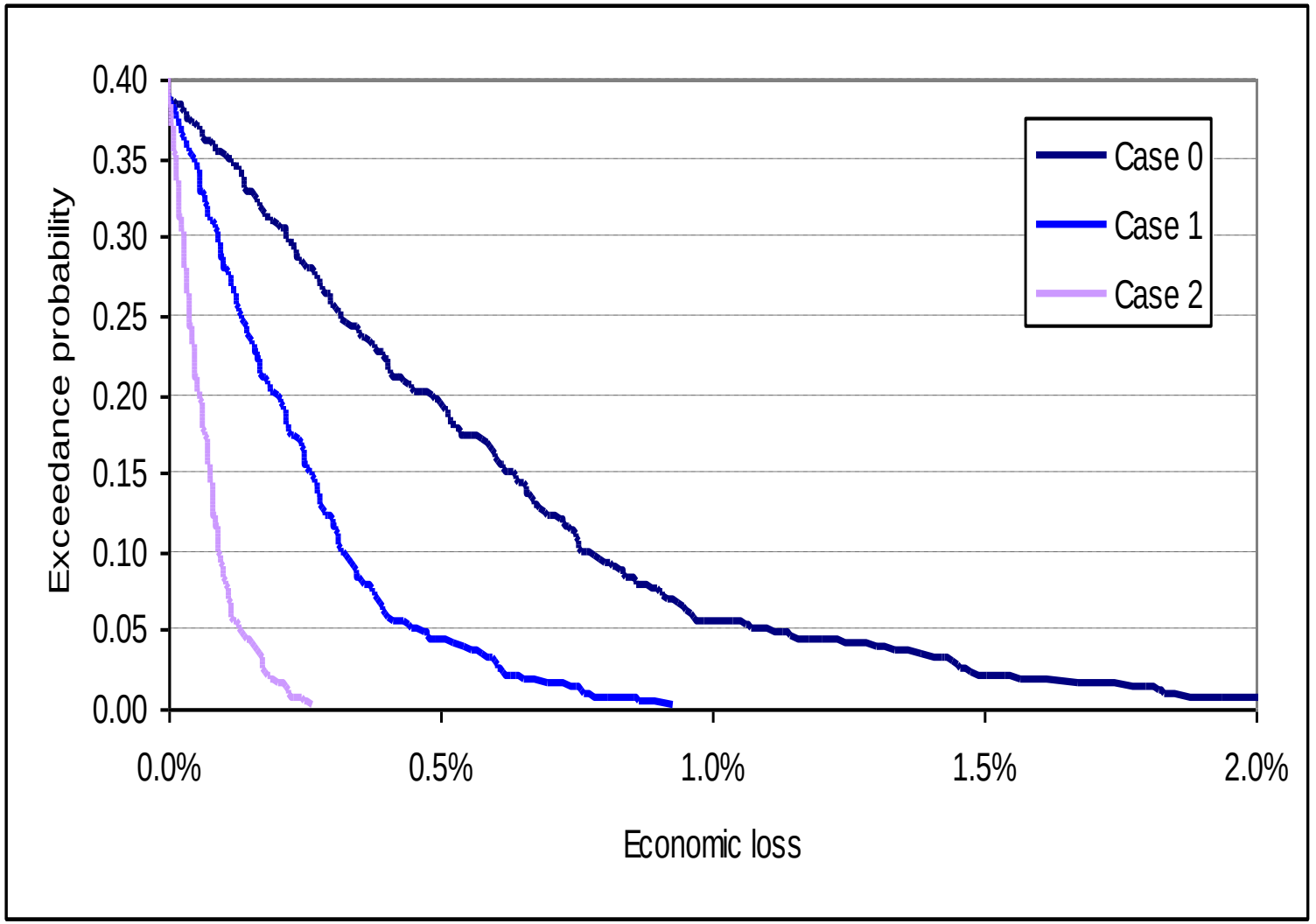
- Resilience to drought is examined through scenarios in the macro-econometric model
  - The baseline Case 0 scenario represents the current economic structure (in terms of GVA).
  - Alternative scenarios, Cases 1 and 2, assume that the share of the agricultural sector decreases,
- The share of the tertiary sector increases significantly

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%

Sector-wise Gross Value Added (GVA) Time Series, 1980–2003, 1993–94 Constant Prices

Simulating the Impact of Structural Changes in the AP Economy (2)

- The maximum possible impact due to a major drought is
  - below 1% of total GVA in Case 1 and
  - well below 0.5 % in Case 2
- The macro-economic impact of drought events
  - is limited at the state level
  - in terms of loss in the total GVA



Key Findings

- Human and social costs
  - ✓Remain devastating for millions of people
  - ✓Effect at the farm level is significant
  - ✓For small and marginal – a loss in output value of 5-10%, fall below the poverty line
- Location differences
  - ✓Vary greatly across locations and crops on drought severity
  - ✓Different crops can be particularly vulnerable in different districts
  - ✓New approaches are needed to adapt to frequent droughts

Key Findings

- Impact on agriculture sector
  - Livelihood, income and employment are directly affected
  - Employment loss for 2002–03 in the agricultural VOP is estimated > 44 lakhs (4.4 Million people).
  - Moderating loss of employment remains a key challenge
- Impact on Households
  - HH losses to drought are varied; tailored assistance would be needed.
- Macroeconomic impact
  - **Less impact** in AP due economy shifts from Ag to other sectors
  - Increased GVA from Manufacturing (secondary) and Service (tertiary) sectors
  - Shift to manufacturing and service could be a powerful drought mitigation strategies

Key Take Away

- Methodology development
  - ✓*developed a robust analytical framework for simulating the long-term impacts of drought at the micro [drought-prone areas] and macro [state] levels*);
- Findings and observations for analysis
  - ✓*conducted a quantitative probabilistic risk assessment of the impacts under different scenarios*; and
- How does EA framework help to proactive drought action
  - ✓*Assisted the GoAP in the development of a futuristic and anticipatory strategy for adapting to frequent drought events and conditions of water deficit*

Thanks!

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Crop Yield Changes under Climate Change Scenarios: Results

- *Climate Change Scenario 1:*
  - Maximum temperature increases by 2°C
  - Minimum temperature increases by 4°C
  - Annual rainy days decrease by 5 percentage points
  - Atmospheric carbon-dioxide at 550 ppm

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

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