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Assessing Vulnerability and Adaptation of Agriculture to Climate Change in Andhra Pradesh

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ABSTRACT

Climate change is characterised by increasing temperatures (especially night temperature), changes in rainfall pattern, increasing frequency of incidence of extreme weather events such as drought, flood, heat wave, cold wave. Understanding what is likely to happen in future helps in planning appropriately and assessment of vulnerability to climate change helps identify the regions that are relatively more vulnerable. It helps to identify, prioritise and target investments and interventions in terms of research, extension, development and policy measures. The present paper makes an assessment of the relative degree of vulnerability for thirteen districts of Andhra Pradesh. Sensitivity and adaptive capacity indices are computed using the data on a range of agro-climatic and socio-economic indicators whereas the exposure index was computed using the climate projections made using the PRECIS for the scenario A1B for the period 2021-50. All the four districts of Rayalaseema were found to be more vulnerable to climate change. Better water management and development of crop varieties that match the changing climate are two important parts of any strategy for resilience. An adaptation intervention in the form of change of crop variety performed better in terms of higher yield and net returns in West Godavari district. Income resilience was found to be better when the livelihoods are more diversified. Technological adaptation interventions like conservation furrows etc., were found to protect yields during a drought year in Anantapur. A survey of a sample of 45 farmers each in Srikakulam and Anantapur districts of Andhra Pradesh was conducted to understand the perceptions on climate change.

Keywords: Vulnerability, Climate change, Risk minimisation, Andhra Pradesh.

JEL: D81, Q25

I

INTRODUCTION

The state of Andhra Pradesh in the present form came into being on June 2, 2014 as a result of the Andhra Pradesh Reorganisation Act. The state has 13 districts out of which nine are along the coast of Bay of Bengal and four are land locked in the southern part. A part of Khammam district, which is now in the Telangana state, was also added to the East and West Godavari districts of the State of Andhra Pradesh.

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The existing data for these two districts do not include this part and this fact is to be borne in mind. The state has a geographical area of 1.602 lakh km^2 with a population of 49.83 million. The state in the current form is more agrarian compared to the undivided state as about 62 per cent of population depends on agriculture as a source of livelihood. Yet, the contribution of agriculture to the state's gross domestic product is only 17 per cent. Though the state is known as 'rice bowl of India', not all is well with agriculture in the state. Some parts, especially the coastal districts, are prone to incidence of cyclones and floods while some other districts, Rayalaseema districts, are chronically drought-prone. The observation of 'crop holiday' when farmers chose not to raise rice in the two Godavari districts in the recent past is a pointer to the problems associated with agriculture in the state. Land degradation associated with indiscriminate use of chemical inputs, sea water ingression, inadequate and undependable rainfall are some of the major problems that cause low productivity of agriculture in the state. Imperfections in the market in terms of inadequate access to markets and market information, inadequacies in market and processing infrastructure are some of the major impediments for realising the potential returns from crop and animal production. The rising cost of inputs is another detriment to the profitability of agriculture. Aggravating all this problems is the climate change that further brings in the urgency to put in place a variety of measures that help improve productivity and profitability of agriculture. Recognising all these dimensions, even the strategy document on transforming agriculture in Andhra Pradesh laid emphasis on making agriculture climate smart (Government of Andhra Pradesh, 2014).

The state consists of a wide range of agro-climatic situations. The Krishna and Godavari zones have high potential in terms of agriculture, the scarce rainfall zone of Rayalaseema presents a challenging situation to making agriculture sustainable. The north coastal zone is unique in the sense that it is relatively well endowed with natural resources and is lagging in the overall socio-economic development.

Need for Building Climate Resilience and Vulnerability Analysis

Climate change is characterised by increasing temperatures (especially night temperature), changes in precipitation/ rainfall pattern, increasing frequency of incidence of extreme weather events such as drought, flood, heat wave, cold wave. Various climate models and the IPCC's Fifth Assessment Report observe that the world is already committed to a certain amount of global warming irrespective of the intensity of mitigation efforts because the benefits of the current mitigation efforts will be realised only after a few decades. What is important is that climate is a spatially variable phenomenon and hence understanding what is likely to happen in future is a useful beginning of planning for measures for making agriculture more resilient to climate change. This paper attempts to assess the relative vulnerability of districts of Andhra Pradesh to climate change, assess the effectiveness of selected adaptation interventions in dealing with drought and flood and understand the perceptions of farmers regarding climate change.

II

DATA AND METHODOLOGY

Vulnerability Assessment

An appropriately planned assessment of vulnerability to climate change helps identify the regions that are relatively more vulnerable to climate change. Vulnerability of an entity, as defined by the IPCC, is a function of sensitivity, exposure and adaptive capacity. The first two components of vulnerability, sensitivity and exposure determine the potential adverse impact of climate change which can be moderated by adaptation determined by adaptive capacity of the entity. Sensitivity is defined as “the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli”. It is determined by demographic and environmental conditions of the region concerned. Exposure is defined as “the nature and degree to which a system is exposed to significant climatic variations”. Thus, exposure relates to climate stress upon a particular unit of analysis (Gbetibouo and Ringler 2009). “A more complete measure of exposure to future climate change would require consideration of projected changes in climate in each analysis unit” (Eriyagama *et al.*, 2012). Adaptive capacity is “the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of the opportunities, or to cope with the consequences”. It is considered to be “a function of wealth, technology, education, information, skills, infrastructure, access to resources, stability and management capabilities” (McCarthy *et al.*, 2001).

In the present context, the three components of vulnerability – sensitivity, exposure and adaptive capacity – are represented through a number of indicators that would reflect them. These indicators were chosen from a broader list of indicators based on review of literature, discussions with experts and nature of relationship with the three components of vulnerability. Table 1 presents the component-wise list of indicators used for computation of vulnerability index.

The process of construction of vulnerability index involves normalisation of all the indicators and then averaging these resultant normalised values. The following formulae were used to normalise different indicators depending on the relationship of the indicator with the dimension:

$$Z_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

when the indicator is positively related to the index

TABLE 1. LIST OF INDICATORS USED IN CONSTRUCTION OF VULNERABILITY INDEX

Exposure (1)	Sensitivity (2)	Adaptive capacity (3)
Change in annual rainfall	Net sown area as per cent GA	Rural poor
Change in June rainfall	Degraded land as per cent GA	SC/ST population
Change in July rainfall	Annual rainfall (normal)	Workforce in agriculture
Change in number of rainy days	Cyclone proneness	Total literacy
Change in MaxT	Area prone to flood incidence	Gender gap
Change in MinT	Drought proneness	Markets
Change in extreme hot day frequency	AWC of soil	Rural electrification
Change in extreme cold day frequency	Stage of groundwater development	Irrigation
Change in drought proneness	Rural population density	Livestock population
Change in incidence of dry spells of >= 14 days	Area operated by small and marginal farmers	Fertiliser consumption
99 percentile rainfall		Ground water availability
Change in number of events with >100 mm rainfall in 3 days		Share of agriculture in district domestic product
Change in highest rainfall in a single day as per cent to annual normal		
Change in highest rainfall in 3 consecutive days as per cent to annual normal		

$$Z_i = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

when the indicator is negatively related to the index

where Z_i is normalised value of i-th district w.r.t. the indicator X,
X_i is the value of indicator in original units for i-th district,
X_{min} is the minimum value of the indicator in original units across the districts,
X_{max} is the maximum value of the indicator in original units across the districts.

The sensitivity and adaptive capacity indicators were computed using the data on a range of agro-climatic and socio-economic indicators whereas the exposure indicators were computed using the climate projections made using the PRECIS for the scenario A1B for the period 2021-50 relative to the period 1961-90. Further details are available in Rama Rao *et al*., 2013. The three indices for sensitivity, exposure and adaptive capacity were constructed by obtaining a weighted mean of the indicators identified. The weights given to each of the indicators were arrived at based on review of literature and a series of discussions with a group of experts actively involved in research for developing appropriate adaptation and mitigation measures and strategies to deal with climate change. The three indices were then averaged (with a weight of 25 per cent to exposure, 40 per cent to sensitivity and 35 per cent to adaptive capacity) to obtain the vulnerability index. It is to be noted that this index is not an absolute measure of damage or risk due to climate change and it is only a relative measure of risk between the districts. It is however helpful in targeting and prioritisation of investments for adaptation. Thus, an analysis of vulnerability helps identify, prioritise and target investments and interventions in terms of research, extension, development and policy measures.

Adaptation Assessment and Farmers' Perceptions

Various adaptation interventions aimed at minimising the losses due to drought and flood were assessed using primary data collected from the farmers. These interventions were assessed for their effectiveness in protecting yields and income in the event of a climatic shock. Data were collected from Anantapur district for drought and from West Godavari district for flood incidence.

Perceptions of farmers with regard to climate change, adaptation and coping were elicited from a random sample of 45 farmers in these villages.

III

RESULTS AND DISCUSSION

Vulnerability and Its Determinants in the Districts of Andhra Pradesh

Table 2 presents the relative degree of vulnerability along with the major determinants of vulnerability in case of the thirteen districts of Andhra Pradesh. It is observed from Table 2 that all the four districts of Rayalaseema were found to be more vulnerable to climate change. The three districts of Chittoor, Anantapur and Kurnool were also categorised as districts with ‘high/very high’ vulnerability even at the country level analysis. A look at the relative position of the districts in terms of the components and the factors leading to vulnerability gives useful guidance as to where and how the investments and interventions are to be planned. For example, a decrease in July rainfall is projected for most districts and this decrease is likely to be highest in Chittoor district. Therefore, it is necessary to alter crop calendars or to explore the possibilities of protecting the crops during prolonged drier month, or a combination of both. Research efforts should take into consideration such possible changes in the rainfall patterns. Similarly, low rainfall and high net sown area as a proportion to geographical area were found to be sensitivity-related factors contributing to vulnerability. It is to be noted here that rainfall, which is relatively lower in the Rayalaseema districts, is also projected to decrease underlining the growing importance to the need for water harvesting as well to devise technological and management options that facilitate more equitable and efficient water use. On the other hand, a higher share of the geographical area being cultivated indicates higher dependence on agriculture of the population warranting the attention towards more sustainable land use and also towards enhancing the opportunities for non-farm employment. The most important adaptive capacity factor is related to irrigation either in the form of area having access to irrigation or in the form of groundwater availability. Investments are therefore needed in expanding the irrigation facilities. As indicated earlier, a more efficient use of irrigation water is also equally important in realising the irrigation potential.

TABLE 2. RELATIVE VULNERABILITY AND DETERMINANTS IN DISTRICTS OF ANDHRA PRADESH

	Rank based on				Most important factor contributing to		
	Vulnerability	Exposure	Sensitivity	Adaptive capacity	Exposure	Sensitivity	Adaptive capacity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chittoor	2	1	7	8	Projected decrease in July rainfall	Low Rainfall	Low groundwater availability
Anantapur	1	2	1	13	Projected decrease in July rainfall	Low Rainfall	Low NIA
Kurnool	3	3	3	12	Projected decrease in July rainfall	Low Rainfall	Low NIA
Kadapa	4	5	2	9	Projected decrease in July rainfall	Low Rainfall	Low groundwater availability
Prakasam	5	8	8	10	Projected decrease in July rainfall	Low Rainfall	Low NIA
Guntur	6	4	4	3	Projected decrease in July rainfall	Low Rainfall	Low groundwater availability
Srikakulam	8	7	10	6	Projected increase in minimum temperature	High NSA	Low groundwater availability
Visakhapatnam	9	11	13	11	Projected increase in minimum temperature	Low Rainfall	Low NIA
Nellore	7	6	9	5	Projected decrease in July rainfall	Low Rainfall	Low groundwater availability
East Godavari	10	9	11	4	Projected increase in minimum temperature	High NSA	Low groundwater availability
Vizianagaram	12	12	12	7	Projected increase in minimum temperature	High NSA	Low groundwater availability
West Godavari	11	10	5	1	Projected decrease in July rainfall	High NSA	Low groundwater availability
Krishna	13	13	6	2	Projected decrease in July rainfall	High NSA	Low groundwater availability

Source: For more details on methodology and measurement of indicators see Rama Rao *et al*., 2013 and Rama Rao *et al*., 2016.; NSA- Net Sown Area; NIA- Net Irrigated Area

Another important dimension of changing climate is the projected increase in both maximum and minimum temperatures. The projected changes ranged from

1.3°C in East Godavari to 2.0°C in Kurnool in case of maximum temperature and from 1.83°C in East Godavari to 2.17°C in Nellore in case of minimum temperature. Increasing minimum temperatures can adversely impact the productivity of rabi crops. Such changes are likely to affect crop growth and productivity and have to be factored in setting up the research agenda for the future.

Thus, better water management and development of crop varieties that match the changing climate are two important parts of any strategy to make Andhra Pradesh agriculture more climate resilient. There are already some promising experiences generated as part of the National Initiative on Climate Resilient Agriculture (NICRA) and elsewhere in this regard.

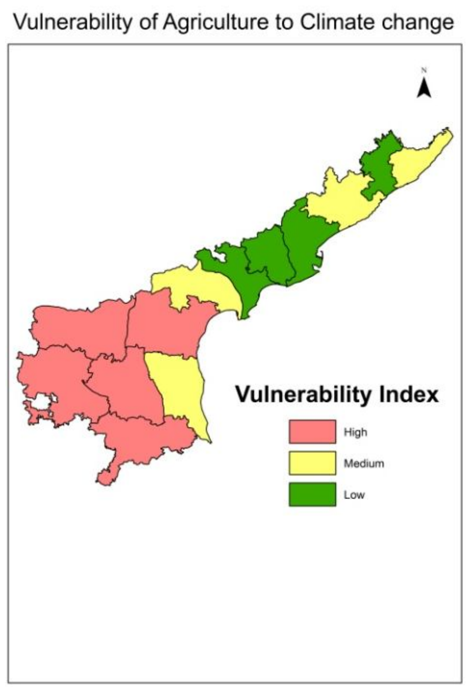

Figure 1. District Wise Vulnerability of Andhra Pradesh

Adaptation to Drought and Flood in Anantapur and West Godavari Districts of Andhra Pradesh

Interventions for Yield and Income Resilience

In an attempt to enhance resilience of crop production to climate variability, various adaptation interventions were evaluated in Anantapur and West Godavari districts as part of NICRA. It was observed that the adaptation intervention in the form of change of crop variety (Indra in place of Swarna) performed better in terms of higher yield and net returns in West Godavari district (Table 3). The yield level even during a flood year like 2013-14 is much closer to the normal yield indicating enhanced resilience to flood situation. The yield of this variety was found to be on par with that of Swarna during the normal rainfall year as well indicating that adoption of this (Indra) variety may be a better option so that yield losses are minimised even in the event of occurrence of a flood. Another major finding is that income resilience is better when the livelihoods are more diversified. Even within agriculture, a more diverse cropping pattern may lead to more stable crop income. However, the analysis also hinted at possible lower income with more diversification in 'normal' years.

TABLE 3. EFFECTIVENESS OF AN INTERVENTION TOWARDS ADAPTATION TO FLOOD INCIDENCE – INTRODUCTION OF FLOOD TOLERANT VARIETY: MTU 1061 IN WEST GODAVARI, ANDHRA PRADESH

Variety (1)	Normal year yield (q/ha) (2)	Flood/ heavy rain year yield (q/ha) (3)	Resilience (stress yield/normal yield (4)
MTU-7029 (Swarna)	21.45 (3.91)	10.15 (3.68)	0.47
MTU-1061 (Indra)	23.47 (3.78)	13.96 (5.10)	0.59

Figures in parentheses are standard deviations.

Similarly, various technological adaptation interventions were found to protect yields during a drought year in Anantapur and thus enhance resilience of yield to drought (Table 4). The adaptation interventions viz., opening conservation furrows, use of seed drill and soil test based fertiliser application methods were found to enhance yield and income resilience to drought in Anantapur district.

TABLE 4. ADAPTATION AND RESILIENCE TO DROUGHT IN ANATAPUR

Yield resilience (1)	Yield, q/ha (2)	Yield lost, q/ha (3)	Resilience (4)
Groundnut+Ppea			
Normal	9.94		
No adaptation/FP	2.08	7.86	0.21
Conservation furrow	2.81	7.13	0.28
Seed drill and thresher	4.11	5.83	0.41
STBFA	3.82	6.12	0.38
Income resilience	NR, Rs./ha	NR lost, Rs./ha	Resilience1
Normal	25729		
No adaptation/FP	-11839	37568	-0.46
Conservation furrow	-3462	29191	-0.13
Seed drill and thresher	713	25016	0.03
STBFA	592	25137	0.02

Farmers' Perceptions to Climate Change

A survey of a sample of 45 farmers each in Srikakulam and Anantapur districts of Andhra Pradesh was conducted to understand the perceptions on climate change. It showed that most farmers believed that climate was changing and the change was being manifested in the form of decrease in seasonal rainfall, untimely rains, increasing incidence of drought and increasingly hotter days and nights (Table 5). Some of these perceptions were in agreement with what is observed through historic data. The increasing temperatures also reflect the projections of various climate models.

TABLE 5. PERCEPTION OF CLIMATE CHANGE FARMERS IN THREE DISTRICTS OF ANDHRA PRADESH (PER CENT FARMERS AGREEING WITH THE STATEMENT, N=45)

Perceptions (per cent) (1)	West Godavari (2)	Srikakulam (3)	Anantapur (4)
Climate is changing	70	100	100
Summers getting hotter	93	100	100
Onset of monsoon delaying	0	2	98
Early withdrawal of monsoon	0	98	74
Total rainfall decreasing	0	100	88
Increasing intra-season droughts	0	0	96
Unusually hot days/heat waves	31	100	80

Farmers were also found to resort to a number of coping ways mostly in the form of consumption adjustments, but increased borrowing was also found to be a coping mechanism leading to indebtedness.

IV

CONCLUSION

The formation of Andhra Pradesh presents an opportune time to have a critical look at the opportunities for and challenges to the growth required in agriculture as the state is predominantly agrarian. Among various factors that threaten the sustainability of agriculture in general and rainfed agriculture in particular is the changing climate which can act as a major impediment to achieving the required growth in productivity, production and profits. Therefore, a regionally differentiated approach is needed as most of the problems and therefore the solutions are spatially variable. Even the relative importance of a given factor varies spatially. The vulnerability analysis helps identify and target appropriate interventions for making agriculture more resilient to changing climate. It is however important to note that any measure that helps farmers cope with the current climate variability will only place them in a better position to deal with future climate change. Accordingly, what is good at present, especially such practices as integrated nutrient and pest management, better water management, will remain relevant even with climate change as these practices aim at reducing use of purchased inputs and save on cost of cultivation. These practices have to be supported by developing improved crop varieties that thrive better in the changed climate. This apart, also required are adjusting crop calendars, sowing and harvesting time, etc., in view of the changes in rainfall patterns. Appropriately designed insurance products that help smoothen income and consumption patterns during a weather-shock and support technology adoption are also need of the hour. Investments are therefore needed in developing appropriate infrastructure and institutions that help generate and implement the strategies for a more resilient agriculture.

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