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Climate sensitivity of crop yields in the former state of Andhra Pradesh, India

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ABSTRACT

Observed meteorological data demonstrates that temperature has increased by 0.74 °C in the last hundred years with the bulk of the warming occurring in the last 50 years. This paper examines the impact of climate change on five major crops in the former state of Andhra Pradesh using district level panel data for the period 1981–2010. Analysis of data shows that crop yields are significantly impacted by climate for rice, tobacco and groundnut. Crops grown in rabi are more susceptible to changes in climate than those in kharif, while drought crops like jowar are found to withstand changes in climate better than others.

1. Introduction

Throughout the world there is significant concern about the effects of climate and its variability on agricultural production. Both simulation (Tubiello and Ewert, 2002; Parry et al., 2004) and experimental research (Kimball et al., 2002) show that while crops would respond favorably to elevated levels of CO_2 in the atmosphere, the associated impact of increasing temperature, changing pattern of precipitation and higher frequency of extreme events like drought and floods would combine to reduce yields and increase risks in agricultural production in several parts of the globe. Climate is crucial in defining production, productivity and acreage for plant species and varieties. Temperature, rainfall (water) and Carbon Dioxide (CO_2) concentration play an important role in crop cycle, and any changes in them would affect crop productivity. Even for crops that are well adapted to their environment, climate's effect on yield remains important (Fofana, 2011).

1.1. Climate change and India

In the Indian context, observed meteorological data highlights that there is significant warming to the tune of 0.50 °C per 100 years during 1901–2007 (Government of India, 2010b). The greater part of warming activity is observed in the last 40 years (1971–2010), and has been particularly attributed to the intense warming in the last decade (1998–2007) (Kothawale et al., 2010). The end of the 20th century witnessed acceleration of surface warming, as minimum (night time) temperature increased by 0.025 °C per year during 1981–1990 and 0.056 °C per year during 1991–2000 (Kumari et al., 2007). Though all seasons exhibited noticeable warming, the increase in winter and post-monsoon temperatures is most marked— by 0.80° and 0.82 °C, respectively over the past 100 years (Ranuzzi and Srivastava, 2012). With regard to precipitation, though the all India monsoon rainfall and frequencies in large scale drought/floods does not show any significant change in trend, many regional variations have been observed in the last century (Prasad and Kochher, 2009).

Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2–4 °C along with increase in precipitation, especially during the monsoon period (Kumar, 2009). PRECIS[1] simulations for 2030 s indicate an all-round warming over the Indian subcontinent, even as the annual mean surface air temperature is projected to rise by 1.7 °C –2.0 °C in 2030 s, while seasons may be warmer by around 2.0 °C. The variability of seasonal mean temperature is projected to be more in winter months. There are also significant spatial variations observed across the country (Government of India, 2010a).

[1] PRECIS: Providing Regional Climates for Impacts Studies is a regional climate modeling system developed at the Met Office Hadley Centre. It is based on the third generation of the Hadley Centre's regional climate model (HadRM3),and helps to generate high-resolution climate change information for different regions

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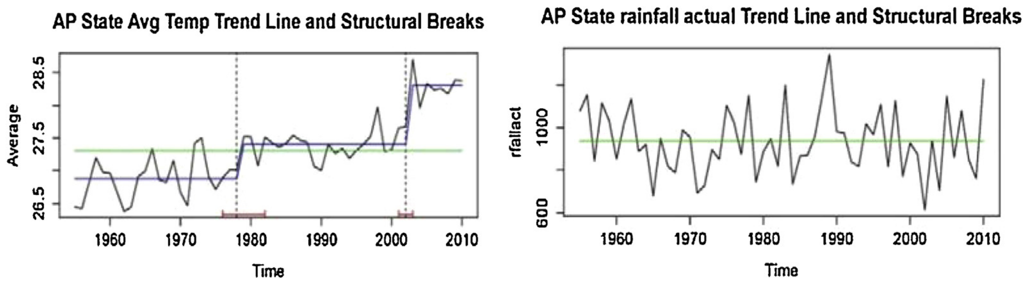

Fig. 1. Climate trends in the former state of Andhra Pradesh 1956–2010.
Source: Indian Water portal and Statistical Abstracts of Andhra Pradesh. Trend graphs generated using R Studio.

1.2. Impact of climate on Indian agriculture

Impact of climate change on Indian agriculture is more pronounced not only due to dependency of substantial proportion of its population on agriculture, but also due to already existing pressure on natural resources and poor coping mechanisms (Pandey et al., 2007; Jasna et al., 2014). Crop specific simulation (Mall et al., 2004; Krishnan et al., 2007) studies for India conclude a definite relation between climate and agriculture productivity. The negative impact of increasing temperature (Sinha and Swaminathan, 1991; Mall and Singh, 2000; Kaul and Ram, 2008) and augmenting negative trend in solar radiation (Pathak et al., 2003) on yields of rice and wheat are well documented. Similarly a one degree increase in mean temperature is also likely to increase irrigation requirement by 10.0% in arid and semi-arid regions of India (Government of India, 2013).

With regard to rainfall, it is well known that increase in droughts and floods, caused by monsoon variability have a major effect on food grain production (Parthasarathy and Pant, 1985; Parthasarathy et al., 1992; Selvaraju, 2003; Mall et al., 2006). Kumar et al. (2004) shows a significant correlation of rainfall and its potential predictors on most of the crops, except sorghum. Given its continental dimensions, one of the peculiar features of Indian climate is its wide spatial variations. For instance though all Indian summer monsoon has not shown an observable changes, at the regional level rainfall has exhibited an increasing or decreasing trend in the last century (Kumar et al., 1992). With regard to temperature, regions in the East coast, West coast and the peninsula showed an increasing frequency of hot days, while Northern India doesn't exhibit this trend (Government of India, 2010a). Indian agriculture is not only affected by rainfall variability but also by shifts in its timings, given that a substantial area is under dry land farming. Even projections for climate indicate that there will be significant regional variations.

Even though impact of climate changes at the state/regional level show consistent results with regard to all India trend, there is also substantial regional variations (Kulkarni et al., 2004; Kandiannan et al., 2008; Das et al., 2009; Gurugnanam et al., 2010; Manickam et al., 2012). It is in this backdrop we attempt to study the impact of climate on crop yields in the former state of Andhra Pradesh, which has now been bifurcated in to two states, namely Telangana and Andhra Pradesh.

1.3. Climate change in the former state of Andhra Pradesh

The region covered by the two new states (Telangana and Andhra Pradesh) of the former state of Andhra Pradesh[2] (A.P) was the fifth largest state in the country both in terms of geographical area (extending over 27.4 million hectares) and population (84.6 million). The region covered by the two new states was also the third largest producer of rice and groundnut, and second in cotton and sunflower. The impact of climate on the performance of this sector is more noticeable due to the fact that half of the undivided state's geographical area lied on the dry lands of Telangana and Rayalaseema, while the other half is vulnerably located on the coastal belt.

There has been a steady and constant increase in annual average, annual maximum and annual minimum temperatures in the former state of Andhra Pradesh during 1956–2010. Observations from meteorological data show that there has been around 1.0° increase in average temperature in the region of the former state of Andhra Pradesh. However with regard to rainfall pattern there is similarity of trend with the all India trend, where the rainfall fluctuations have been largely random over a century with no systematic change (Padakandla, 2014) Fig. 1.

Analysis of crop yield growth show that there is a steady deceleration over the recent period, even though farm inputs like irrigation and fertilizer have witnessed a steady uptick during the same period Fig. 2 (Padakandla, 2014) Table 1.

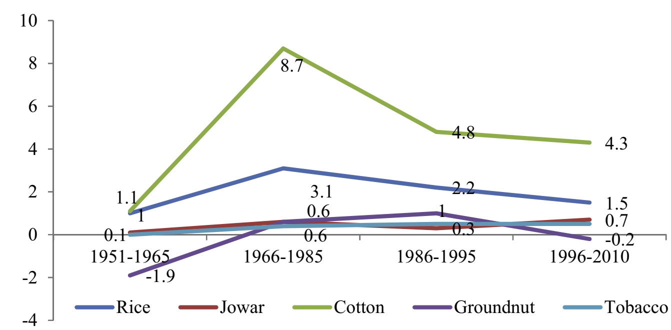

Fig. 2. Yield growth of principal crops in the former state of Andhra Pradesh.
Source: Season and Crop reports 1951–2010, GOAP (Calculated by author)

Table 1
Crop wise irrigated area in the former state of Andhra Pradesh (as% of GCA).

Crop	1951–1965	1966–1985	1986–1995	1996–2010
Rice	92.1	94.1	94.9	96.0
Jowar	1.2	1.0	1.6	5.8
Cotton	1.1	7.1	12.9	18.7
Groundnut	5.9	15.2	18.7	17.4
Tobacco	14.1	14.5	30.7	26.7

Source: season & crop reports 1951–2010, GOAP. Calculated by the author.

[2] Andhra Pradesh here represents the undivided state of Andhra Pradesh, that is now bifurcated in to two separate states of Telangana and Andhra Pradesh. With over 27.4 million hectares geographical area the undivided state was bigger than United Kingdom.