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Effect of Climate on Productivity of Pigeonpea and Cotton in Andhra Pradesh – A Panel Data Regression

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ABSTRACT: This paper was attempted to examine the effect of temperature and rainfall on the productivity of two important crops-pigeonpea and cotton in Andhra Pradesh following panel data regression approach. Using the district level time series data, the yield of each of these two crops was regressed on maximum temperature during kharif, rainfall quantity and number of rainy days for the period 1990-2002, in a one-way and two-way fixed effect models of panel regression using Least Squares Dummy Variable Method. Comparison of district specific effects revealed statistically significant differences between districts in case of pigeonpea. The response coefficients for rainfall and number of rainy days were found significant at 5 per cent level. A positive impact on yield of pigeonpea at the rate of 1.9 kg/ha was observed for a 10 mm rise in rainfall. The number of rainy days was found to have a significant negative relationship with yield. In case of cotton, half of the major cotton growing districts differed significantly in mean yield levels. A significant reduction in yield at a rate of 13 kg/ha for every 1^0C rise in the maximum temperature was observed. The yield of cotton was found to increase by 0.7 kg/ha for every 10 mm increase in the rainfall.

Key words: Climate change, pigeonpea, cotton, panel regression

There is now adequate evidence about the impending climate change and the consequences thereof. The fourth assessment report of IPCC observed that 'warming of climate system is now unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea level' (IPCC, 2007). Though climate change is global in its occurrence and consequences, it is the developing countries like India that face more adverse consequences. Globally, climate change is seen as a failure of market mechanisms wherein the polluters did not have to pay for the negative externalities (Stern, 2007).

John *et al.* (2008) studied the impact on yield of sorghum, maize, groundnut and pigeonpea of reduced rainfall, increased temperature and increased CO_2 concentration in semi-arid tropics of Zimbabwe in a simulation experiment using APSIM. The study reported that impact of increased temperature (3.1^0C rise in maximum and minimum temperature) was dramatic causing 16% reduction in yield in the two cereals and 31% and 3 % yield reductions in groundnut and pigeonpea respectively. Silim *et al.* (2007) tried to study the impact of photoperiod and temperature on flowering of redgram in Kenya and could not find clear patterns in sensitivity to temperature. Shalander *et al.* (2011) reported a positive relationship between detrended yield and rainfall and number of rainy days with major dryland crops, namely, sorghum, pearl millet and maize. Rise in maximum temperature led to reduced yields in majority districts.

Climate change projections made upto 2100 for India indicate an overall increase in temperature by $2\text{-}4^0$C with no substantial change in precipitation quantity (Kavikumar, 2010). However, different regions are expected to experience differential change in the amount of rainfall that is likely to be received in the coming decades. The Western Ghats, the Central Indian and North Eastern parts of the country are projected to receive higher amount of rainfall. Another significant aspect of climate change is the increase in the frequency of occurrence of extreme events such as droughts, floods and cyclones. These expected changes will have adverse impacts on climate sensitive sectors such as agriculture, forest and coastal ecosystems and also on availability of water for different uses and on human health.

Andhra Pradesh is an agriculturally important state in India. Rice, sorghum, groundnut, pigeonpea, chickpea, cotton and sugarcane are the important crops grown in the state. Rainfed agriculture is dominant in many districts of Telangana and Rayalaseema regions of the state. The rainfed regions are home to much of the production of coarse cereals, pulses, oilseeds and cotton.

Among pulses, pigeonpea is the most important crop as it is the major source of protein and the crop is grown largely under rainfed conditions. However, during the last decade (2001-02 to 2009-10), the area sown to pigeonpea did not show any significant trend in Andhra Pradesh while growth in production and productivity were also marginal. Mahabubnagar, Prakasam, Adilabad, Nalgonda, Rangareddy, Kurnool, Guntur and Medak are the important pigeonpea growing districts in the state. During the last decade, pigeonpea production in Nalgonda registered a substantial growth, at the rate of 14% per annum (compound growth rate), largely due to increasing growth in area (6.18% per annum) under cultivation. On the other hand, the area under the crop declined (6.39% per annum) in Guntur indicating that the crop is being replaced by other crops.

Cotton is another important commercial crop grown in the state. ITC (2011) studied the impacts of climate change on cotton production. The crop is grown in the regions with relatively higher temperature and any further rise in temperature may be deleterious to crop yields as it will lead to increased shedding of flower buds. The rise in temperature could have a positive effect on yields, though, in those areas and regions where the effective fruiting period is squeezed between two phases of lower temperatures: one early in the season to start effective flowering and boll formation, and another at maturity that results in termination of fruit formation. Boll retention is more sensitive to high temperatures than any other condition, except for nutrient deficiency, which is relatively easy to correct. While it is not possible to avoid the effects of high temperatures, this condition can produce bud shedding, which is the most common reason for loss of fruit forms (Reddy *et al.* 1999). It was also observed that higher temperature regimes decreased boll size and the maturation period. Reddy *et al.* (2000) observed that boll growth decreases significantly and fruit is shed 3–5 days after blossom in temperatures over 32º C. Trend in area and yield expansions of cotton in Andhra Pradesh were significant at 5% level with 5.44% and 6.50% per annum, respectively while production trend became significant at 1% level with growth of 12.30% per annum during the period 2001-02 to 2009-10. Adilabad, Warangal, Karimnagar, Nalgonda, Khammam, Mahabubnagar and Guntur are the major cotton producing districts accounting for about 80 per cent of the area under the crop in the state. The growth rate of area sown under the crop in Karimnagar was as high as 18 per cent (compound) per annum. Growth in productivity was found to be faster in Warangal, Nalgonda and Karimnagar districts. The productivity in Mahabubnagar was highly fluctuating. The productivity growth was found to be relatively slower in Khammam and Guntur districts, where the crop has a long history.

As the two crops are grown during kharif season and are long duration in nature, climate is an important determinant of productivity. It is therefore important to understand the scope for cotton and pigeonpea farmers to adapt to the changing climate. In this paper, an attempt was made to examine the effect of climate, represented by the maximum temperature, rainfall and number of rainy days on productivity of pigeonpea and cotton.

Data and Methodology

An attempt was made in this paper to examine the effect of temperature and rainfall on the productivity of two important crops – pigeonpea and cotton - in Andhra Pradesh using the district level time series data on crop productivity, maximum temperature during kharif, rainfall during kharif and number of rainy days for the period 1990-2002. The districts having at least 5000 ha of area sown under the crop were included in the analysis. Data on number of rainy days and maximum temperature were based on grid-level data of Climate Research Unit, East Anglia University, UK. District level estimates derived from the grid data and hosted on website http://www.indiawaterportal.org were used in the analysis. Data on quantity of rainfall was taken from the Centre for Monitoring Indian Economy (CMIE). Data on productivity of crops were obtained from the CMIE and Directorate of Economics and Statistics, Government of Andhra Pradesh.

To minimise the bias in the estimates of linear sensitivities, a panel data regression was followed. The technique of panel regression can provide linear sensitivities after adjusting for cross section and time series effects in the form of intercepts. Two variants of panel regression and pooled regression were used in the analysis. The models used are as under:

Pooled regression model (disregarding space and time dimensions)

This model assumes that all coefficients are constant across cross section units (districts) and time. It is as follows.

$$Y_{it} = \beta_1 + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + u_{it}$$

Where i stands for district and t stands for year

Y_{it} is the yield of ith district in tth year

β_1 is the intercept

β_2, β_3 and β_4 are linear sensitivities corresponding to rainfall (X_2), No. of rainy days (X_3) and maximum temperature (X_4).

X s are non-stochastic and error term u_{it} follows classical assumptions.

One-way fixed effect model of panel regression

In this model slope coefficients are assumed constant over time and space but intercept varies over cross section units. The model formulation is as under.

$$Y_{it} = \alpha_1 + \alpha_2 D_2 + ... + \alpha_i D_i + ... + \alpha_k D_k + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + u_{it}$$

Where D_i s are dummy variables such that D_i=1 if the observation belongs to ith district, else D_i=0 (for i=2,3,...,k)

k is the number of cross section units (districts) in the data set.

α_1 becomes the intercept for district-1 and α_2 is the deviation of intercept of district-2 from that of district-1 and α_3 is the deviation of intercept of district-3 from that of district-1 and so on. As a result, intercept for ith district is given by $\alpha_1+\alpha_i$ (for $i\neq1$).

The model gives linear yield response coefficients to predictors included in the model after accounting for the district specific differences. Using the district level time series data of Andhra Pradesh state, the yield of each crop was regressed on maximum temperature during kharif, rainfall quantity and number of rainy days, in a one-way fixed effect model of panel regression. The coefficients were estimated following Least Squares Dummy Variable (LSDV) Method.

Two–way fixed effect model of panel regression

This model assumes that slope coefficients are constant over time and space but intercept varies over cross section units and time. The model is as under:

$$Y_{it} = \alpha_1 + \alpha_2 D_2 + ... + \alpha_i D_i + ... + \alpha_k D_k + \omega_2 T_2 + ... + \omega_t T_t + ... + \omega_p T_p + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + u_{it}$$

Where T_2 to T_p are dummies for years 1990 to 2001 and ω_2 to ω_p are respective intercepts and α_1 is an intercept for year 2002 as well as district-1.

p is the number of years.

The model gives yield response coefficients after accounting for the district and year specific differences.

The best fit model in terms of coefficient of determination and significance of regressor variables were used for inference.

Results and Discussion

There were 17 districts cultivating pigeonpea in more than 5000 ha. The results of panel regression of district level yield of pigeonpea on quantity of rainfall, number of rainy days and maximum temperature are furnished in Table 1. During the analysis, intercept role was assigned to Chittoor district. As a result, district specific effects of other districts were computed as deviation from Chittoor intercept value. For example the deviation for East Godavari district is 482. It means that the intercept for East Godavari would be Chittor intercept + East Godavari deviation = 660 + 482 =1142. Panel regression employed here assumes that intercept varies with district and slope coefficients don't vary with district. The results in Table 1 validated our assumption. Twelve out of 16 intercepts differed significantly from the intercept of Chittoor at 5% level of significance. It confirms that the intercepts of various districts are not equal. As a result R^2 value has increased from 0.11 to 0.52 with consideration of differential intercepts for districts as compared to pooled regression. These differential intercepts reflect the differences in the natural resource endowments and other district specific factors. Chittoor district recorded the lowest productivity intercept among 17 districts. As far as natural resources are concerned, Adilabad is bestowed with relatively better rainfall and soils. Its low yield intercept might be due to poor management practices. The average productivity in East Godavari district differed most from that of Chittoor. East Godavari was followed by Guntur district (over 454 kg/ha). The intercepts of Adilabad, Anantapur, Medak and Mahabubnagar did not differ significantly from that of Chittoor.

When a model with differential intercepts for districts as well as for years was fitted, R^2 increased to 0.67. However, difference in year intercepts was not very substantial (Table 2) and only two years differed significantly (at 5% level) from the intercept of 2002. Moreover no weather variable was found significant at 5% level. The variation in weather variables might have been captured through variation in year specific effects. Hence the model was not considered further. It was evident from the slope coefficients in Table 1 that yield of pigeonpea was not much influenced by variation in maximum temperature (though the coefficient was negative it was not significant at 5% level). However, quantity of rainfall played a significant role in influencing the productivity with a coefficient of 0.19 kg/ha per 1 mm of rainfall. It was also observed that the number of rainy days had a significant negative relationship with yield which might be attributed to occurrence of rain during flowering stage.

The results of pooled regression of pigeonpea yield on climate variables were furnished in Table 3. In this case also, sensitivities corresponding to rainfall and number of rainy days were significant and slope coefficient corresponding to maximum temperature was not significant. However, one can see that there is huge reduction in size of critical region (Pr > |t|) for all the three slope coefficients when compared to that of panel regression. In other words, sensitivities from pooled regression attributed overemphasis to climate variables considered.

There were 18 districts in Andhra Pradesh growing cotton in more than 5000 ha. The results of panel regression of cotton yield on the three weather variables considered were presented in Table 4. The R^2 value increased from 0.10 to 0.57 with consideration of differential intercepts for districts as compared to pooled regression. In case of cotton, Adilabad recorded lowest intercept value followed by Anantapur. Eight out of the 17 intercepts significantly differed from the intercept of Anantapur. Guntur district followed by Krishna district were reported to have higher intercept values.

Table 1 : Results of panel regression for pigeonpea data with differential intercepts for districts

Variable	Estimate	SE	t Value	Pr > |t|
Intercept (Chittoor) α_1	660	284	2.32	0.02
Adilabad	34	58	0.60	0.55
Karimnagar	213	70	3.02	<0.01
Medak	95	54	1.76	0.08
Rangareddy	192	54	3.55	<0.01
Mahbubnagar	96	58	1.67	0.10
Nalgonda	121	57	2.12	0.04
Warangal	180	58	3.11	<0.01
Khammam	300	58	5.15	<0.01
Visakhapatnam	208	64	3.22	<0.01
East Godavari	482	86	5.60	<0.01
Krishna	310	57	5.40	<0.01
Guntur	454	59	7.66	<0.01
Prakasam	198	59	3.36	<0.01
Cuddapah	235	54	4.37	<0.01
Kurnool	172	61	2.82	0.01
Anantapur	64	58	1.12	0.27
Covariates				
Rainfall	0.19	0.06	2.97	<0.01
No. of rainy days	-6.66	2.84	-2.35	0.02
Max. temperature	-9.54	7.88	-1.21	0.23
$R^2 = 0.52$				

When a model with differential intercepts for districts as well as for years was fitted, R^2 increased to 0.67. The results were shown in Table 5. In case of cotton also, the differences in year specific effects were not found to be substantial (only one year differed from the intercept of 2002 at 5% level of significance). Regression coefficient was found significant for rainfall alone. Further, between years weather variation, to some extent, would have got accounted through year specific effects. Therefore, the results based on one way fixed effect model of panel regression were used for inference. It can be observed in Table 4 that maximum temperature exerted a significantly negative influence on productivity with a coefficient of -13.05 kg/ha. It means that each 1^0C rise in maximum temperature from the average would cause an yield loss of about 13 kg/ha. As the rise in temperature is almost imminent as per the climate change literature, it will pose a threat to cotton cultivation in Andhra Pradesh state.

Table 2 : Results of panel regression for pigeonpea data with differential intercepts for districts as well as years

Variable	Estimate	SE	t Value	Pr > |t|
Intercept (Chittoor/2002) α_1	952	881	1.08	0.28
Adilabad	64	96	0.66	0.51
Karimnagar	155	92	1.69	0.09
Medak	73	58	1.26	0.21
Rangareddy	190	60	3.14	<0.01
Mahbubnagar	104	66	1.58	0.12
Nalgonda	129	67	1.93	0.06
Warangal	223	82	2.72	0.01
Khammam	347	95	3.65	<0.01
Visakhapatnam	160	95	1.69	0.09
East Godavari	525	114	4.59	<0.01
Krishna	355	79	4.51	<0.01
Guntur	501	88	5.73	<0.01
Prakasam	239	85	2.82	0.01
Cuddapah	214	49	4.39	<0.01
Kurnool	207	71	2.91	<0.01
Anantapur	8	72	0.11	0.92
1990	-142	60	-2.38	0.02
1991	27	48	0.57	0.57
1992	-58	51	-1.14	0.26
1993	25	61	0.41	0.68
1994	6	59	0.11	0.91
1995	33	91	0.36	0.72
1996	43	68	0.63	0.53
1997	-125	68	-1.86	0.07
1998	121	83	1.46	0.15
1999	16	42	0.38	0.70
2000	29	50	0.58	0.56
2001	107	45	2.40	0.02
Covariates				
Rainfall	0.03	0.07	0.46	0.65
Max. temperature	-22.68	23.62	-0.96	0.34
No. of rainy days	-0.65	4.97	-0.13	0.90
$R^2 = 0.67$				

Table 3 : Results of pooled regression with pigeonpea

Variable	Estimate	SE	t Value	Pr > |t|
Intercept	112	264	0.42	0.67
Rainfall	0.27	0.07	3.88	<0.01
No. of rainy days	-8.72	2.44	-3.57	<0.01
Max. temperature	12.07	6.98	1.73	0.09
$R^2 = 0.11$				

The slope coefficient of rainfall was positive as expected and significant at 5% level of significance. The results indicate that a 10 mm of rainfall increase may lead to an yield rise of 0.7 kg/ha. Though the number of rainy days showed a positive relationship with yield, the coefficient (0.60) was not significantly different from zero at 5% level of significance.

The results of pooled regression of cotton yield on climate variables were given in Table 6. As far as slope coefficients of rainfall and number of rainy days are concerned, there was slight reduction in p values for rainfall and number of rainy days. The findings with panel regression still hold good. However, there was a radical reduction in p value corresponding to maximum temperature, from pooled regression (0.99) to panel regression (<0.01).

In the light of the above results, it can also be concluded that pooled regression may be used with caution especially when cross section specific effects are operating. If there exists no variation between cross section effects (after fitting panel regression) it is advised to go by the results of pooled regression.

Table 4 : Results of panel regression for Cotton data with differential intercepts for districts

Variable	Estimate	SE	t Value	Pr > |t|
Intercept (Anantapur) α_1	572	137	4.18	<0.01
Adilabad	-57	36	-1.60	0.11
Nizamabad	7	32	0.21	0.83
Karimnagar	151	34	4.50	<0.01
Medak	22	31	0.70	0.48
Rangareddy	15	31	0.47	0.64
Mahbubnagar	15	31	0.47	0.64
Nalgonda	10	31	0.33	0.74
Warangal	108	34	3.14	<0.01
Khammam	90	36	2.50	0.01
Vizianagaram	40	42	0.94	0.35
East Godavari	148	39	3.77	<0.01
Krishna	170	34	4.97	<0.01
Guntur	222	35	6.34	<0.01
Prakasam	111	34	3.23	<0.01
Nellore	149	40	3.72	<0.01
Cuddapah	23	30	0.76	0.45
Kurnool	37	33	1.13	0.26
Covariates				
Rainfall	0.07	0.03	2.10	0.04
No. of rainy days	0.60	1.57	0.38	0.70
Max. temperature	-13.05	4.03	-3.24	<0.01
$R^2 = 0.57$				

Table 5 : Results of panel regression for cotton data with differential intercepts for districts as well as years

Variable	Estimate	SE	t Value	Pr > |t|
Intercept (Anantapur/2002)α_1	558	475	1.17	0.24
Adilabad	-64	82	-0.78	0.44
Nizamabad	3	60	0.05	0.96
Karimnagar	153	75	2.05	0.04
Medak	19	57	0.33	0.74
Rangareddy	10	56	0.17	0.86
Mahbubnagar	4	53	0.08	0.94
Nalgonda	1	56	0.01	0.99
Warangal	94	69	1.36	0.17
Khammam	79	79	0.99	0.32
Vizianagaram	77	70	1.10	0.27
East Godavari	144	82	1.76	0.08
Krishna	156	67	2.34	0.02
Guntur	206	71	2.90	<0.01
Prakasam	97	69	1.40	0.16
Nellore	138	76	1.82	0.07
Cuddapah	19	38	0.50	0.62
Kurnool	18	46	0.38	0.70
1990	-15	35	-0.41	0.68
1991	51	26	1.97	0.05
1992	3	28	0.09	0.93
1993	73	35	2.10	0.04
1994	28	34	0.84	0.40
1995	30	53	0.56	0.57
1996	54	38	1.42	0.16
1997	19	37	0.52	0.60
1998	-52	45	-1.15	0.25
1999	-5	24	-0.23	0.82
2000	11	27	0.42	0.68
2001	34	23	1.44	0.15
Covariates				
Rainfall	0.10	0.03	2.87	<0.01
No. of rainy days	-1.21	2.95	-0.41	0.68
Max. temperature	-11.14	13.21	-0.84	0.40
$R^2 = 0.67$				

Table 6 : Results of pooled regression with cotton

Variable	Estimate	SE	t Value	Pr > |t|
Intercept	198	150	1.32	0.19
Rainfall	0.14	0.04	3.89	<0.01
No. of rainy days	-1.12	1.42	-0.79	0.43
Max. temperature	-0.05	3.94	-0.01	0.99
$R^2 = 0.10$				

Conclusion

Positive and statistically significant linear sensitivities to rainfall observed in case of pigeonpea and cotton underscores the need for life saving irrigation or to evolve varieties whose phenology is in tune with the changing rainfall pattern. The potential of various soil and water conservation technologies including different planting methods such as ridge and furrow methods can be exploited. The key finding of this study remains the highly significant negative sensitivity of cotton yield to maximum temperature. It calls for the development of germplasm that can withstand rise in maximum temperature in cotton. Further, use of panel regression is a better method of handling the spatial differences in a regression framework.

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