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Research Paper

Factors influencing productivity of major crops in various districts of Gujarat: A socio-economic analysis in the context of climate change

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ABSTRACT : Climate change is likely to intensify the variability of summer monsoon dynamics and its impact on the productivity of crops is inevitable. In order to study the impact of climate change on the productivity of selected crops of Gujarat, an econometric bio-model of crop production was attempted. Cobb Douglas production function was fitted as it gave the best fit according the statistical criteria of high co-efficient of multiple determination (R^2) and low standard error. Seven climatic and socio-economic variables affecting crop yields were selected. The district wise results revealed that there was no consistency in the nature of impact (positive or negative) of the selected climatic and socio-economic variables on the crop yields in different districts due to vast diversity in the agro-climatic conditions and uncertainty in the timing of rainfall *i.e.*, the stage at which the rainfall might have occurred. However, since the majority of the results were found to be significant there is a need to focus on investments in adaptation research capacity: particularly, in the development of climate proof crops (drought resistant and heat tolerant varieties) as well as redeploying the existing improved crop varieties that can cope with wide range of climatic conditions.

KEY WORDS : Cobb Douglas production function, Climate change, Adaptation, Crop productivity

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INTRODUCTION :

The climate change phenomenon is not new. It has been and continues to be, a major source of fluctuation in food production, particularly in the semi-arid tropical countries of the developing world like India. In concurrence with other physical, political and socio-economic factors, climate change also contributes to economic loss, hunger, famine and migration. In the developing countries where adoption of improved adaptation and mitigation technologies is slow climatic irregularities prevent the regular supply and availability of food, the key facets of food security. Hence, it is imperative that weather and climate aspects should be thoroughly premeditated so as to formulate sustainable strategies and policies to promote food production and food security. Climate affects agriculture, a fact well known to every farmer IPCC (2007). The main drivers of agricultural responses to climate change are biophysical effects and socio-economic factors. Crop production is affected biophysically by meteorological variables, including rising temperatures, changing precipitation regimes and increased atmospheric carbon dioxide levels. Biophysical effects of climate change on agricultural production will be positive in some agricultural systems and regions and negative in others and these effects will vary through time (Rao and Joshi, 2009). Socio-economic factors inûuence responses to changes in crop productivity.

The Southwest monsoon, which accounts for nearly 75 per cent of India's rainfall, is most critical for agriculture. Year-to-year variation in yields is basically due to variation in temperature, precipitation that can make the difference between bountiful "bumper" crops and economic wreck. Climate change is likely to intensify the variability of summer monsoon dynamics and its impact on the production and productivity of crops is inevitable. In order to study the impact of climate change on the productivity of the selected crops in various districts of Gujarat, an econometric bio-model of crop production was taken for the present study.

MATERIALS AND METHODS :

The data pertaining to various agricultural indicators were collected and compiled from different sources *viz.*, Directorate of Economics and Statistics, Gandhinagar and Department of Agriculture and Co-operation, Gandhinagar. Meteorological data (temperature and rainfall) were collected from the Meteorology Departments of Anand Agricultural University, Anand and Junagadh Agricultural University, Junagadh.

In order to study the impact of climate change on the productivity of the selected crops in various districts of Gujarat, an econometric bio-model of crop production was attempted. For the purpose of our study, the list of crops belonging to different districts is given in Table 1.

The chosen crops are predominantly grown in monsoon and any change in climate, particularly rainfall and temperature would affect the productivity of these crops significantly. Agricultural production depends not only on climate related variables, but also on the use of several factors like fertilizer, labour and other resources. For the purpose of our study, linear and Cobb-Douglas production functions were estimated and out of these two functions, Cobb-Douglas form gave the better fit as per the statistical criteria of high co-efficient of multiple determination (R^2) and low standard error. Thus, Cobb Douglas function was finally retained.

The following multiple regression model was used to examine the cause and effect relationship between productivity of various crops and the selected explanatary variables mentioned below:

Y = f (F,HL, AR, NR, DFNR, MAXTEMP, MINTEMP)

where,

Y= Crop yield on per hectare basis (kg/ha)

F= Fertilizer used per hectare (kg/ha)

HL= Human labour in hours/ha

AR= Actual annual rainfall (mm)

NR= Normal rainfall (mm)

DFNR= Deviation from normal rainfall (mm)

MAXTEMP = Mean maximum temperature during crop season (^oC)

MINTEMP= Mean minimum temperature during crop season (^oC).

RESULTS AND DATA ANALYSIS :

In order to study the impact of climate change on the productivity of the selected crops in various districts of Gujarat, Cobb Douglas production function was finally retained as it gave the best fit according the statistical criteria of high co-efficient of multiple determination (R^2) and low standard error.

The district-wise results of regression analysis for the selected crops are presented in Table 2 to 15.

A perusal Table 2 indicated that 47.3 per cent of the variation in the *Jowar* yield around its mean was explained by the selected explanatory variables in case of Bharuch district. Out of these variables, actual rainfall had a positive and significant effect on the yield at five per cent level. The yield of jowar crop increased by 0.562 per cent with every one per cent increase in the rainfall. Contrary to this, deviation from the normal rainfall (DFNR) had a negative co-efficient (-0.099) implying a negative and significant impact on the productivity of *Jowar.*

Maize crop was selected for Panchmahal district considering its significance in the region. 88 per cent of the variation in yield was explained by the selected explanatory variables, out of which, human labour had a highly significant and positive impact on the yield (Table 3). Moreover, fertilizer use also had a positive and significant impact on the yield at 10 per cent level significance. The variables pertaining to normal rainfall and mean maximum temperature during the crop growth period had significant impact on the maize productivity. The results showed that one per cent increase in the

Table 1: List of selected crops by districts of Gujarat

Sr. No.	Agro-climatic zones of Gujarat	Selected districts	Crops
1.	Middle Gujarat	Anand	Tobacco and *Bajra*
		Vadodara	Cotton
		Ahemdabad	Cotton
		Panchmahal	Maize
2.	North Gujarat	Banaskantha	*Bajra*
3.	South Gujarat	Surat	Paddy
		Bharuch	*Jowar*
4.	Southern hills (Heavy rainfall)	Navsari	Paddy
5.	North Saurashtra	Amreli	Groundnut
		Rajkot	Groundnut
6.	South Saurashtra	Junagadh	Groundnut and cotton
7.	Northwest arid zone	Kutch	*Bajra*

Table 2 : Estimates of parameters influencing *Jowar* yield in Bharuch district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t – value
Intercept	21.657	17.427	1.243
Actual fertilizer (kg/ha)	0.266	0.343	0.777
Human labour (hrs/per ha)	-0.223	0.617	-0.361
Actual RF (AR) (mm)	0.562**	0.214	2.630
Normal RF (NR) (mm)	-3.888	2.419	-1.607
DFNR	-0.099**	0.037	-2.690
Mean max temp during crop season (degrees centigrade)	-1.901	3.321	-0.573
Mean min temp during crop season (degrees centigrade)	4.694	5.762	0.815
R^2	0.473		

** indicate significance of values at P=0.05

Table 3 : Estimates of parameters influencing maize yield in Panchmahal district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t – value
Intercept	-29.567	12.637	-2.340
Actual fertilizer (Kg/ha)	0.442*	0.224	1.971
Human labour (hrs/per ha)	2.274***	0.289	7.865
Actual RF (AR)(mm)	0.295	0.406	0.725
Normal RF (NR) (mm)	-1.723**	0.670	-2.572
DFNR	0.051	0.079	0.648
Mean max temp during crop season (degrees centigrade)	7.190**	3.264	2.203
Mean min temp during crop season (degrees centigrade)	1.361	3.662	0.372
R^2	0.880		

*, ** and *** indicate significance of values at P=0.1; 0.05 and 0.01, respectively

Table 4 : Estimates of parameters influencing *Bajra* yield in Banaskantha district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t-value
Intercept	53.112	13.726	3.870
Actual fertilizer (kg/ha)	0.327	0.297	1.102
Human labour (hrs/per ha)	0.203	0.289	0.701
Actual RF (AR) (mm)	0.211	0.270	0.782
Normal RF (NR) (mm)	-6.108**	2.642	-2.312
DFNR	0.033	0.093	0.359
Mean max temp during crop season (degrees centigrade)	-2.251	1.786	-1.260
Mean min temp during crop season (degrees centigrade)	-0.722	1.248	-0.578
R^2	0.652		

** indicate significance of value at P=0.05

Table 5: Estimates of parameters influencing *Bajra* yield in Kutch district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t – value
Intercept	26.325	30.413	0.866
Actual fertilizer (kg/ha)	-0.169	0.308	-0.549
Human labour (hrs/per ha)	-0.100	0.246	-0.408
Actual RF (AR) (mm)	0.049	0.238	0.204
Normal RF (NR) (mm)	0.840	3.866	0.217
DFNR	0.147	0.109	1.358
Mean max temp during crop season (degrees centigrade)	-3.781*	2.085	-1.813
Mean min temp during crop season (degrees centigrade)	-3.295	2.231	-1.477
R^2	0.784		

***** indicate significance of value at P=0.1

Table 6 : Estimates of parameters influencing *Bajra* yield in Anand district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t – value
Intercept	-11.499	11.131	-1.033
Actual fertilizer (kg/ha)	0.212	0.200	1.061
Human labour (hrs/per ha)	-0.031	0.255	-0.120
Actual RF (AR) mm	-0.137	0.212	-0.645
Normal RF (NR) (mm)	1.551**	0.722	2.149
DFNR	0.078	0.069	1.125
Mean max temp during crop season (degrees centigrade)	3.977**	1.821	2.184
Mean min temp during crop season (degrees centigrade)	-1.765	2.117	-0.834
R^2	0.461		

**indicate significance of value at P=0.05

Table 7: Estimates of parameters influencing paddy yield in Surat district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t – value
Intercept	6.451	4.365	1.478
Actual fertilizer (kg/ha)	-0.104	0.106	-0.973
Human labour (hrs/per ha)	0.058	0.269	0.215
Actual RF (AR) mm	-0.032	0.083	-0.382
Normal RF (NR) (mm)	-0.255	0.306	-0.833
DFNR	0.033	0.019	1.698
Mean max temp during crop season (degrees centigrade)	0.385	0.403	0.956
Mean min temp during crop season (degrees centigrade)	0.552	0.552	0.999
R^2	0.473		

Table 8 : Estimates of parameters influencing paddy yield in Navsari district, Gujarat (1989-90 to 2008 09) (n=20)

Variables	Co-efficients	Standard errors	t - value
Intercept	204.600	83.754	2.443
Actual fertilizer (kg/ha)	-0.983	0.704	-1.396
Human labour (hrs/per ha)	0.373	1.975	0.189
Actual RF (AR) (mm)	0.324	0.870	0.373
Normal RF (NR) (mm)	-23.999**	9.182	-2.614
DFNR	-0.194	0.146	-1.331
Mean max temp during crop season (degrees centigrade)	-4.350	8.910	-0.488
Mean min temp during crop season (degrees centigrade)	-0.226	7.198	-0.031
R^2	0.564		

** indicate significance of value at P=0.05

normal rainfall led to 1.72 per cent decrease in the yield but a one per cent increase in the mean maximum temperature led to a 7.19 per cent increase in the yield. The negative impact of normal rainfall could be probably attributed to the excess rainfall during the crop growth period as maize crop is very susceptible to excess water while the positive impact of mean maximum temperature may be due to the fact that maize is a warm weather crop having an optimum temperature requirement of 32°C during the crop growth period.

So far as *Bajra* crop is concerned, it was seen that in majority of the districts in which the crop was selected, the variables pertaining to normal rainfall and mean maximum temperature during the growing season of the crop had a significant impact on the productivity at five per cent level of significance (Tables 4, 5 and 6). However, there was no consistency in the nature of impact (positive or negative) due to vast diversity in the agro-climatic

Table 9 : Estimates of parameters groundnut yield in Rajkot district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t – value
Intercept	0.500	53.248	0.009
Actual fertilizer (kg/ha)	-0.578	0.954	-0.606
Human labour (hrs/per ha)	1.867	1.169	1.597
Actual RF (AR) (mm)	2.093**	0.798	2.623
Normal RF (NR) (mm)	-1.040	1.910	-0.545
DFNR	0.045	0.215	0.209
Mean max temp during crop season (degrees centigrade)	-6.515	6.507	-1.001
Mean min temp during crop season (degrees centigrade)	4.106	9.655	0.425
R^2	0.799		

** indicate significance of value at P=0.05

Table 10 : Estimates of parameters groundnut yield in Amreli district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t – value
Intercept	-19.696	20.361	-0.967
Actual fertilizer (kg/ha)	-0.216	0.608	-0.356
Human labour (hrs/per ha)	2.166*	1.093	1.982
Actual RF (AR) (mm)	0.816*	0.434	1.881
Normal RF (NR) (mm)	2.959	1.720	1.721
DFNR	0.098	0.140	0.697
Mean max temp during crop season (degrees centigrade)	-5.070*	2.736	-1.853
Mean min temp during crop season (degrees centigrade)	2.017	1.718	1.174
R^2	0.688		

* indicate significance of value at P=0.1

Table 11 : Estimates of parameters groundnut yield in Junagadh district, Gujarat (1989-90 to 2008-2009) (n=20)

Variables	Co-efficients	Standard errors	t - value
Intercept	-32.719	19.003	-1.722
Actual fertilizer (kg/ha)	0.512*	0.253	2.021
Human labour (hrs/per ha)	0.436	0.651	0.669
Actual RF (AR) (mm)	0.602**	0.256	2.349
Normal RF (NR) (mm)	2.967*	1.670	1.777
DFNR	0.060	0.059	1.030
Mean max temp during crop season (degrees centigrade)	-2.921	2.041	-1.432
Mean min temp during crop season (degrees centigrade)	6.399	3.780	1.693
R^2	0.877		

* and ** indicate significance of values at P=0.1 and 0.05, respectively

Table 12: Estimates of parameters influencing cotton yield in Vadodara district, Gujarat (1989-90 to 2008-2009) (n=20)

Variables	Co-efficients	Standard errors	t - value
Intercept	-26.425	21.577	-1.225
Actual fertilizer (kg/ha)	-0.327	0.308	-1.059
Human labour (hrs/per ha)	0.488	0.606	0.805
Actual RF (AR) (mm)	0.620	0.445	1.394
Normal RF (NR) (mm)	2.184	1.838	1.188
DFNR	-0.040	0.110	-0.363
Mean max temp during crop season (degrees centigrade)	3.526	3.980	0.886
Mean min temp during crop season (degrees centigrade)	-0.482	2.334	-0.207
R^2	0.556		

Table 13 : Estimates of parameters influencing cotton yield in Ahmedabad district, Gujarat (1989-90 to 2008-09) (n = 20)

Variables	Co-efficients	Standard errors	t - value
Intercept	-21.222	41.159	-0.516
Actual fertilizer (kg/ha)	0.413	0.292	1.415
Human labour (hrs/per ha)	-0.850	0.620	-1.371
Actual RF (AR) (mm)	0.860**	0.367	2.345
Normal RF (NR) (mm)	2.948	6.064	0.486
DFNR	-0.088	0.081	-1.094
Mean max temp during crop season (degrees centigrade)	1.081	3.516	0.308
Mean min temp during crop season (degrees centigrade)	0.605	1.711	0.354
R^2	0.531		

** indicate significance of value at P=0.05

Table 14 : Estimates of parameters influencing cotton yield in Junagadh district, Gujarat (1989-90 to 2008-09) (n=20)

Variables	Co-efficients	Standard errors	t - value
Intercept	0.443	18.313	0.024
Actual fertilizer (kg/ha)	-0.443	0.290	-1.529
Human labour (hrs/per ha)	0.600	0.592	1.013
Actual RF (AR) (mm)	0.341	0.540	0.632
Normal RF (NR) (mm)	6.121*	3.583	1.709
DFNR	0.113	0.121	0.935
Mean max temp during crop season (degrees centigrade)	-4.662	6.686	-0.697
Mean min temp during crop season (degrees centigrade)	-8.178	4.736	-1.727
R^2	0.593		

* indicate significance of value at P=0.1

Table 15 : Estimates of parameters influencing tobacco yield in Anand district, Gujarat (1989-90 to 2008 09) (n=20)

Variables	Co-efficients	Standard errors	t - value
Intercept	-3.405	5.655	-0.602
Actual fertilizer (kg/ha)	0.115	0.121	0.951
Human labour (hrs/per ha)	0.338	0.308	1.098
Actual RF (AR) (mm)	-0.060	0.068	-0.886
Normal RF (NR) (mm)	0.699	0.478	1.463
DFNR	0.009	0.017	0.501
Mean max temp during crop season (degrees centigrade)	0.233	0.605	0.385
Mean min temp during crop season (degrees centigrade)	1.000*	0.515	1.943

* indicate significance of value at P=0.1

conditions of different districts and uncertainty in the timing of rainfall *i.e.*, the stage at which the rainfall may have occurred.

The results for paddy crop in Surat district and cotton crop in both Baroda and Junagadh districts (Table 7, 12, 14 and 15) suggest that neither the input variables (actual fertilizer and human labour) nor the climatic variables had a significant impact on the productivity of these crops.

For Navsari District, paddy crop was selected. In spite of paddy being a water loving crop, the impact of normal rainfall on its productivity was found to be negative and significant (Table 8). The negative impact may be attributed to excess and untimely rainfall at the grain filling stage of the crop period.

Groundnut crop was selected for the districts of Rajkot, Amreli and Junagadh of the Saurashtra region because of its significance in this zone. The results presented (Table 9 to 11) revealed that 79.9, 68.8 and 87.7 per cent of the variation in the yield was explained by the selected explanatory variables in Rajkot, Amreli and Junagadh districts, respectively. It was found that the impact of actual annual rainfall on the productivity of groundnut turned out to be positive and significant indicating sufficient quantum and relatively even distribution of rainfall during different stages of the crop growth period. The variables pertaining to actual fertilizer use and human labour also had a significant impact at 10 per cent level of significance in Junagadh and Amreli districts, respectively.

In case of cotton crop in Ahmedabad district, 53.1 per cent of the variation in the yield was explained by the selected explanatory variables (Table 13). Actual rainfall was found to have a positive and significant impact at five per cent level of significance. It was found that one per cent increase in the actual rainfall led to an increase in the yield by 0.860 per cent.

Tobacco crop was selected for Anand district. Only 44.53 per cent of variation in the yield was explained by all the variables, out of which, the impact of mean minimum temperature during the crop season was found to be both positive and significant *i.e.*, one per cent increase in the mean minimum temperature led to one per cent increase in the crops yield (Table 14). The reason may be due to the fact that lower temperature increases the growth period of tobacco crop.

Since the agricultural sector was found to have greater vulnerability to climate change in the different periods, there is a need to focus on investments in adaptation research capacity: particularly, in the development of climate proof crops (drought resistant and heat tolerant varieties) as well as redeploying the existing improved crop varieties that can cope with wide range of climatic conditions. An improvement in the agronomic practices of different crops such as revising planting dates, plant densities and crop sequences can help cope with the delayed rainy seasons, longer dry spells and earlier plant maturity. Also, technologies for minimizing soil disturbance such as reduced tillage, conservation agriculture and crop rotation must be adopted (Kaul, 2006).

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