Sustainability of Crop Production Under Changing Climate Pattern in the Chhattisgarh Region of Central India

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Abstract

The Chhattisgarh region of Central India has an average annual rainfall of about 1400 mm and rice is the major crop grown mostly in rainfed conditions under 'broadcast *biasi*' system of cultivation. Out of the three agroclimatic zones (ACZs) in this region viz., i) Chhattisgarh Plains, ii) Bastar Plateau and iii) Northern Hills, the latter two ACZs are inhabited predominantly by native tribes.

There are some pockets in this region where rainfall is decreasing significantly during last 4-5 decades. Though the rainfall is decreasing the agrotechnology developed in the recent decades has increased the productivity of rice and other crops.

In this paper, the sustainability of the productivity of rice and other crops has been examined using the 'Sustainable Yield Index (SYI) which is :

$$SYI = \frac{Y - \sigma}{Y_{\max}}$$

Where Y = Average productivity of a given crop under given management over time.

σ = Standard deviation of the productivity of the data set.

$Y_{\max}$ = Highest productivity of the data set

In tradition bound and predominantly native tribal areas and with poor socioeconomic conditions, the agricultural inputs like chemical fertilizers, insecticides/pesticides etc., are very meager and hence the agricultural sustainability in these areas can be assessed from crop productivity and its variability.

In this paper the sustainability of the important crops is examined in view of the changing rainfall pattern. In unsustainable production areas, the causes for the unsustainable productivity are examined. Remedial measures for improving the productivity either through water harvesting or through crop diversification have been suggested.

Key Words : Sustainability, Climate Change, Crop Production Growth Rate.

1. Introduction

The green revolution in India in the mid sixties created impressive achievements but bypassed the rainfed areas limiting the achievements to irrigated areas only.

In Chhattisgarh region of Madhya Pradesh State in Central India comprising 3 agroclimatic zones (Fig. 1) the productivity of rice very low (1-1.5 t/ha). With about 1400 mm of average annual rainfall of which about 90 percent is received during the SW monsoon season (June-September), rice is grown in about 3.8 million hectares mostly under rainfed conditions and by broadcast method of sowing and *bushening* (locally called *biasi*) about 30-40 days after sowing. Earlier studies (Baghel and Sastri, 1993; Sastri and Urkurkar, 1995) revealed that there is a significant decreasing trend of rainfall in some pockets of each of the 8 districts but, the productivity of rice has still increased due to technological developments (Anonymous, 1996).

In this paper the changing rainfall pattern, the productivity and sustainability of rice and other crops for all the districts are discussed in detail.

2. Area and Productivity trends of Different Crops in Chhattisgarh Region

i) Growth rates of area

It can be seen from Table 1 that in Chhattisgarh plains highest growth rate of rice area was in respect of Raigarh while least in Bilaspur district during the study period of 1977-78 to 1991-92.

In case of wheat, there are negative growth rates of area in all the districts of Chhattisgarh Plains and also in Bastar Plateau. In Northern Hills the growth rate of wheat is increasing at the rate of 3.66 percent per year. The negative growth rates of wheat in Chhattisgarh Plains are due to increasing winter season temperatures (Fig. 2).

The chickpea area is increasing in all the districts of Chhattisgarh Plains zone and Bastar Plateau and is decreasing in Northern Hills. In Chhattisgarh Plains zone, lathyrus (grass pea), is being replaced by chickpea. In Northern Hills zone, chickpea is being replaced by wheat. The linseed area is also decreasing in all the districts of Chhattisgarh Plains and Bastar Plateau zones while it is increasing in the Northern Hills.

Fig. 2: Maximum and Minimum temperatures pattern in January and February at Raipur
(Data base : 1901 - 94)

Table 1 : Growth Rates (Percent /year) of the Area and Productivity of some important crops in different districts of Chhattisgarh region.

Districts	Rice		Wheat		Chickpea		Groundnut		Linseed		Pigeonpea	
	A	P	A	P	A	P	A	P	A	P	A	P
Raipur	0.56	3.63	-1.18	2.87	15.45	1.93	1.77	2.79	-8.17	6.68	-2.24	2.61
Durg	0.80	2.55	-2.00	3.94	6.59	4.55	33.83	2.61	-4.89	3.78	-2.92	5.54
Rajanadgaon	0.82	0.78	-1.93	4.13	7.32	2.88	7.04	3.61	-3.67	4.60	-0.99	3.58
Bilaspur	0.44	5.39	-1.79	6.76	2.20	1.54	25.94	3.88	4.96	4.03	-1.54	3.88
Raigarh	1.18	2.38	-6.47	4.73	0.0	1.77	4.57	4.36	4.57	3.21	0.43	3.12
Balaghat	0.52	1.08	2.21	14.08	3.09	3.17	-13.0	2.20	-1.99	5.08	2.18	3.57
Chhattisgarh Plains	0.71	2.69	-1.13	5.90	5.60	2.47	6.31	3.29	-3.14	4.44	-1.35	3.51
Bastar Plateau	1.32	1.85	-2.57	2.35	0.72	2.63	-	-	-4.48	3.90	3.22	6.10
Northern Hills	1.21	3.62	3.66	4.01	-1.17	2.48	19.73	3.44	2.53	3.74	3.52	4.26

A = Area , P = Productivity

ii) Growth rates of productivity

The productivity of all crops is increasing in all the 3 ACZs. In the Chhattisgarh Plains, with 6 districts, the range of the growth rates of productivity of different crops is as follows :

Crop	Range of growth rates of productivity (percent/year)	Crop	Range of growth rates of productivity (percent/year)
Rice	0.78 to 5.39	Groundnut	2.20 to 4.36
Wheat	2.87 to 14.08	Linseed	3.21 to 6.68
Chickpea	1.54 to 4.55	Pigeonpea	2.61 to 5.54

The regression equations of the area and productivity trends of some crops for the 3 ACZs given in Table 2. The decreasing trends of linseed and increasing trends of chickpea areas in Chhattisgarh Plains are highly significant while the increasing trend of wheat productivity is significant only in Chhattisgarh Plains zone. The increasing trends of the productivity of other crops are not significant in Chhattisgarh Plains.

Table 2 : Regression equations of the trendlines of area and productivity of some important crops in the 3 agroclimatic zones.

Crop		Regression equations for the zone		
		Chhattisgarh Plains	Bastar Plateau	Northern Hills
Rice	Area	$Y = 443.5 + 3.25 X (0.32)$	$Y = 453.5 + 6.94 X (0.92)**$	$Y = 269.9 + 3.02 X (0.90)**$
	Prod.	$Y = 820.3 + 23.9 X (0.27)$	$Y = 752.5 + 16.4 X (0.30)$	$Y = 604.7 + 24.2 X (0.28)$
Wheat	Area	$Y = 19.6 - 0.25 X (0.18)$	$Y = 3.3 + 0.07 X (0.87)**$	$Y = 12.5 + 0.57 X (0.51)*$
	Prod.	$Y = 461.5 + 52.6 X (0.66)**$	$Y = 888.1 + 24.7 X (0.54)**$	$Y = 690.8 + 34.4 X (0.45)$
Pigeonpea	Area	$Y = 6.9 - 0.09 X (0.37)$	$Y = 1.9 + 0.06 X (0.28)$	$Y = 5.3 + 0.25 X (0.69)**$
	Prod.	$Y = 759.8 + 32.3 X (0.)$	$Y = 720.9 + 60.5 X (0.45)$	$Y = 798.7 + 43.1 X (0.53)*$
Linseed	Area	$Y = 223.0 - 8.95 X (0.52)*$	$Y = 6.1 + 0.22 X (0.68)**$	$Y = 4.6 + 0.13 X (0.24)$
	Prod.	$Y = 114.2 + 6.67 X (0.43)$	$Y = 147.6 + 7.36 X (0.65)**$	$Y = 134.1 + 5.51 X (0.26)$
Chickpea	Area	$Y = 15.8 + 1.38 X (0.82)**$	$Y = 2.0 + 0.02 X (0.05)$	$Y = 7.4 + 0.07 X (0.04)$
	Prod.	$Y = 407.7 + 11.6 X (0.44)$	$Y = 338.8 + 11.3 X (0.52)**$	$Y = 337.1 + 8.95 X (0.39)$

Figures in parentheses indicate R square values, * Significant at 1 % level , ** Significant at 5 % level

In Bastar Plateau, the increasing trend of rice and decreasing trends of wheat and linseed areas are highly significant. The increasing productivity trends of wheat, linseed and chickpea are significant while the increase of the productivity of other crops is not significant.

In the Northern Hills zone, the increase of rice, wheat and Pigeonpea area is significant and the same for other crops are not significant.

3. Rainfall Pattern

i) Rainfall distribution

Table 3 shows the average seasonal and annual rainfall and rainy days and their spatial variability of different districts in Chhattisgarh region.

Durg district has the lowest annual and seasonal (June to September) rainfall while the highest seasonal rainfall is in Raigarh district and highest annual rainfall is in the Bastar district. Durg has the lowest seasonal rainy days while Raipur has the lowest annual number of rainy days. The highest seasonal as well as annual number of rainy days are in Raigarh district. The highest variability of seasonal rainfall and rainy days is in Bastar district (1130-1637 mm) while the highest variability of annual rainfall and least variability of rainy days are in Balaghat district. The highest variability of annual number of rainy days is in Raigarh district while the least variability is in Rajnandgaon district.

Table 3 : District wise seasonal (June-September) and annual rainfall and corresponding rainy days and their spatial variability.

Districts	Average district statistics				Spatial variability in each district			
	Seasonal Rainfall		Annual Rainfall		Seasonal Rainfall		Annual Rainfall	
	Rainfall (mm)	Rainy Days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days
Raipur	1277.0	51	1384.9	62	1054-1385	43-56	1195-1549	54-69
Durg	1020.4	50	1186.9	63	940-1264	46-55	1121-1359	55-67
R'gaon	1021.8	52	1232.0	65	850-1142	50-54	1108-1332	63-67
Raigarh	1413.6	63	1516.7	78	1268-1468	55-65	1445-1726	68-92
Bilaspur	1219.3	58	1391.7	71	957-1403	53-64	1190-1544	66-75
Surguja	1200.5	61	1493.2	76	1015-1262	52-61	1344-1657	64-76
Bastar	1315.5	61	1532.2	76	1130-1637	53-67	1371-1788	68-83
Balaghat	1277.7	59	1527.5	75	1212-1710	57-64	1392-1897	67-76

ii) Changing rainfall pattern

Analysis of the historical rainfall data (1901-1990) of the district headquarters in Chhattisgarh region reveals that there is not much decreasing rainfall pattern in these districts. However, in Raipur district there are some pockets where there is significant decreasing pattern in annual rainfall (Fig. 3) indicating that the regional or micro-regional changes of rainfall are highly significant and are detrimental in crop production especially for rice.

iii) Rainfall pattern and rice productivity :

An analysis of the recent rainfall data (1971 onwards) revealed that the rainfall in recent two decades is decreasing almost in all districts. Though the rainfall is decreasing the productivity of rice is increasing with higher gradients in Raipur, Bilaspur and Balaghat districts due to development of irrigation in Raipur and Bilaspur districts and due to higher quantum and stable rainfall in Balaghat district.

In Bastar and Surguja, the predominantly native tribal population districts, the increase of rice productivity is negligible, though the quantum of rainfall is still higher than in other districts. This is due to negligible use of inputs and hence there is a great potential to increase the productivity.

4. Sustainability

i) Concepts of sustainability

According to UNEP, the sustainable development is defined as 'improving the quality of human life while living within the carrying capacity of supporting ecosystems'. The agricultural sustainability according to FAO (1989) is that 'sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of environment and conserving the natural resources'. Edwards (1987) defined sustainable agriculture as 'integrated systems of agriculture production that are less dependent on high inputs of energy and synthetic chemicals and are more dependent on intensive management rather than conventional monoculture systems'.

ii) Sustainable yield index (SYI)

All the concepts of sustainability now in vogue, point out that sustainable agriculture is one which makes use of low cost inputs, less chemical fertilizers, maintain soil fertility and ecological harmony. Most often sustainability is considered in qualitative terms only. Singh et. al. (1990) tried to quantify sustainability using the 'Sustainable Yield Index' (SYI) given as :

Fig. 3: Trends of annual rainfall at different stations in Raipur district.

$$SYI = \frac{Y - \sigma}{Y_{\max}}$$

Where Y = Average productivity of a given crop under given management over time.

σ = Standard deviation of the productivity of the data set.

$Y_{\max}$ = Highest productivity of the data set

The sustainable yield indices (SYI) of all major crops are computed using the data from 1977-78 to 1992-93. Using the SYI, the sustainability of the productivity of these crops is quantified as using the following criterion :

SYI range	Sustainability
Grater than 0.7	Highly Sustainable (HS)
0.7 to 0.5	Sustainable (S)
0.5 to 0.3	Unsustainable (U)
Less than 0.3	Highly Unsustainable (HU)

Using the above criterion, the sustainability of the productivity of some important crops has been examined as shown in Table 4.

Table 4 : Sustainable Yield Indices and the status of different crops in 3 agroclimatic zones of Chhattisgarh region.

Crop	Agroclimatic Zones					
	Chhattisgarh Plains		Bastar Plateau		Northern Hills	
	SYI	Status	SYI	Status	SYI	Status
Rice	0.63	S	0.73	HS	0.48	U
Small Millets	-	-	0.62	S	0.41	U
Wheat	0.38	U	0.66	S	0.58	S
Groundnut	0.62	S	-	-	0.61	S
Chickpea	0.67	S	0.63	S	0.71	HS
Lathyrus	0.36	U	-	-	-	-
Linseed	0.50	S/U	0.60	S	0.46	U
Pigeonpea	0.55	S	0.47	U	0.56	S
Maize	-	-	0.55	S	0.54	S
Mustard	0.58	S	-	-	-	-
Soybean	0.74	HS	-	-	-	-

The productivity of wheat, lathyrus in Chhattisgarh Plains, pigeonpea in Bastar Plateau and rice, small millets and linseed in Northern Hills are unsustainable. The rice productivity in Bastar Plateau, chickpea productivity in Northern Hills and soybean productivity in Chhattisgarh Plains are highly sustainable. The productivity of linseed in Chhattisgarh Plains is in the border of sustainable and unsustainable productivity levels.

The causes of low sustainability are either low average productivity or high standard deviation (higher fluctuations) or both. The maximum yield is the productivity potential of that crop using a given management.

To minimize the yield gap and variability, it is necessary to critically examine the causes of low productivity and high variability. For example, one of the causes of low productivity of rice in this region is the low plant population after *biasi* or *bushening* operation. The cause of high variability in respect of wet season crops like rice, small millets, maize, pigeonpea is the high rainfall variability and for winter crops like wheat, mustard, chickpea etc., higher fluctuations of temperatures are responsible for unsustainability. For crops like linseed and lathyrus, which are usually grown as relay crops in rice, rainfall in the initial stages and temperature in later stages are responsible for higher productivity fluctuations.

5. Conclusions

It has been found that there are varying trends of the areas and productivity of different crops in the 3 agroclimatic zones (ACZs). It was observed that there is decreasing rainfall in some pockets of some districts. Such trends are not discernible at district level. However, the rainfall in the last two decades is decreasing at all districts. But the rice productivity for the corresponding period is increasing due to technological development.

The productivity of a few crops in the 3 ACZs is unsustainable. The reasons of the low sustainability are either low average productivity or high variability or both. The causes of low productivity for rice are low plant population and intermittent drought in wet season and changing temperature in winter season.

Technologies like providing life saving irrigation through farm-ponds for alleviation of drought and diversification crops in unproductive areas are being developed. The increasing area of soybean crop as a substitute for small millets is an example of the efforts of crop diversification and the soybean productivity is highly sustainable in this area.

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