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Influence of Area and Yield on the Production of Rice in Chhattisgarh Plain

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A B S T R A C T

Predictive models for the rice crop (*Oryza sativa* L.) of Chhattisgarh plain and its constituent districts have been made. Models have been fitted for the area, productivity and production of the crop separately for above region. Based on these models prediction of area productivity and production of rice have been made year wise between 1998-99 to 2013-14. The partial compound growth rates of the area, production and productivity of the crop have been also estimated and discussed. Periodic effect of five years as well as annual effects was found to be working in most of the districts/region based on a postulated and estimated production function of area and productivity. It was found that the major influencing factor on the production of rice was its area. This influence of area was around 60 percent for mostly districts of the Chhattisgarh plain.

Introduction

India accounts for only about 2.4 % of the world's geographical area and 4 % of its water resources, but has to support about 17 % of the world's human population and 15% of the livestock. Agriculture is an important sector of the Indian economy, accounting for 14% of the nation's GDP, about 11% of its exports, about half of the population still relies on agriculture as its principal source of income and it is a source of raw material for a large number of industries. It occupies 32% of the area under food grains and contributes 42% of total food grains production in the country. During 2011-12, there was record production of food grains at 259.32 million tones, of which 131.27 million tones was during Kharif season and 128.05 million tons during the Rabi season. Of the total food grains production, production of cereals was 242.23 million tones the production of rice (both kharif and rabi) is estimated at 101.8 million tones (Ghosh, 2011).

Agriculture is counted as the chief economic occupation of the Chhattisgarh state. According to a government estimate, net sown area of the state is 4.828 million hectares and the gross sown area is 5.788 million hectares. About 80% of the population of the state is rural and the main livelihood of the villagers is agriculture and agriculture based small industry. Paddy is main crop of Chhattisgarh. Chhattisgarh is popularly known as "rice bowl" of India and occupies

an area of around 3.61 million hectare with the production of 5.4 mt. and productivity of 1517 kg/ha (Anonymous, 2010b). The productivity of rice in the state is 1.52 tone/ ha, which is far behind the productivity of India (1.9 tone/ ha), china (6.3 tone/ ha), Japan (6.4 tone/ ha) and Egypt (8.4 tone/ ha).The present study is therefore, an attempt had been made to develop reliable predictive models for the area, production and productivity of cereals for Chhattisgarh Plain, its constituent districts. Production function had also been developed to know the extent of influence of area and productivity on production.

Materials and Methods

The secondary data on area, productivity and production of rice crop were collected for the period 1998-99 to 2013-14 from the web site of Chhattisgarh Government www.cgstate.gov.in. In this period there are ten districts in Chhattisgarh plain namely Raipur, Mahasamund, Dhamtari, Durg, Rajnandgaon, Kawardha, Bilaspur, Janjgir, Korba and Raigarh due to the formation of new districts.

During analyses it was realized that a five year periodic effect is working on the response variable in most of the districts/region. Therefore, this periodic effect was considered as a structural effect changing every five years the area, production and productivity scenario of rice crop probably due to some research or technical break-through, etc. After fitting such structural/ periodic effects, i.e. α's, it was found in most cases that they were showing a trend over the three periods in almost all districts and slopes (β's) were not significantly different for these periods. Due to these reasons a periodic effect variable 'P' was introduced to measure the periodic trend along with the annual effect variable 'T' to measure annual trend with in each period. So, the following multiple regression models was finalized and fitted in all cases using stepwise regression technique as described.

$$\ln Y = \ln t + bp\ P + bt\ T + \in \quad (1a)$$

Or

$$\ln \hat{Y} = \ln t + bp\ P + bt\ T \quad (1b)$$

Where,

$\ln \hat{Y}$ = expected value of the natural logarithm of the response variable.

Y = area, productivity (i.e. yield) or production of given a region.

ln t = intercept.

P= periodic time Variable, taking values from 1 to 3 signifying Pd I, i.e., first period for 1998-99 to 2003-04, Pd II for 2004-05 to 2008-09 and Pd III for 2009-10 to 2013-14.

T = annual time variable taking values from 1 to 5 signifying the 1^{st}, 2^{nd},3^{rd},4^{th} or 5^{th}, year for any period 1 to 3.

bp = partial linear regression coefficient corresponding to variable P.

bt = partial linear regression coefficient corresponding to variable T.

$\in$ = error/disturbance component.

Lastly, our interest is to find the extent of influence of area and productivity on the production of cereal crops in Chhattisgarh plain. For that we need an additive model with an error term. We have the identity,

Production = Area × Productivity.

However, in actual practice the area, production and productivity are not always reported to be accurate enough to equal to above product, due to probably rounding errors and many a times due to human error in recording the data.

Therefore, assuming that actual area, production and productivity are some powers of the reported data and representing the residual discrepancies with an error term, this identity can be written in the functional form. Then, after taking natural logarithms, denoting the error compound by $\in' \sim N(0,\sigma^2_{\in'})$ and then introducing the intercept term we can have the following linear statistical model

$\widehat{ln}P(A, Y) = c_0 + c_1 \ln A + c_2 \ln Y + \in'$ (2a)

Or, $\widehat{ln}\ P(A, Y) = c_0 + c_1 \ln A + c_2 \ln Y$ (2b)

Or, $\hat{P}(A, Y) = d_0 A^{c1} Y^{c2}$, $d_0 = e^{c0}$ (2c)

Where A, Y and $\hat{P}$ (A, P) denote the area, productivity and estimated production of a given region. The constant c_0 is the intercept and (c_1, c_2) are the partial regression coefficients corresponding to variables ln A and ln Y respectively.

Results and Discussion

Partial compound growth rate of area, production and yield of rice was for period (1998-99 to 2012-13) and presented in Table 1. It was observed that from the Table 1 Chhattisgarh plain had registered statistically significant increasing periodic partial compound growth rate in area (2.780 percent), productivity (28.617 percent) and production (32.193 percent) at 1 percent level.

The annual compound growth rate for area, productivity and production were found (0.588 percent), (4.203 percent) and (4.816 percent) respectively and non-significant. Among all districts of the Chhattisgarh plain zone for almost the entire district's the model showed highly significant partial regression for the periodic variable area except Bilaspur, Janjgir, Korba and Raigarh districts. The time variable showed significant growth rate for Dhamatari district only (0.0347) at 5 percent level. No other district showed significant partial regression coefficient for time variable. The model showed significant partial regression coefficient for all of the districts for the variable production. No district except Dhamatari (0.1425) at 10 percent level showed significant regression coefficient for time variable under study.

While studying productivity the table 1 revealed that almost all of the districts except Korba showed significant partial growth rate. It can also be observed from the table that no district including complete Chhattisgarh plain zone showed significant growth rate for the time variable.

Production function

To know the extent of influence of area and productivity on the production of Rice the postulated production function is given by equations 2(a), 2(b) and 2(c). The estimated production in terms of area and yield for the period has been presented in Table 2.

It revealed from Table 2 that for Rajnandgaon, Kawardha, Mahasamund and Durg districts the production function satisfactorily fits to the data as indicated by more than 70%. The model showed highest R^2 up to 98.898 percent for Rajnandgaon district. The column designated (1) and (2) gives the breakup of the total percent sum of squares explained by the production component, ln P (A, Y) in to its percent sum of square explained by the area component ln A and the yield component ln Y.

Table.1 Prediction models (w.r.t time) of area and production under rice for C.G. plain and its constituent districts using model (1) for Period1998-99 to 2012-13

District/Region		Int	bp	%r_1 @	bt	% r_2 @	% R^2
	A	6.2059	0.0190***	1.9168	0.0060	0.5979	69.27
Raipur	Y	6.6630	0.2274**	25.5286	-0.0022	-0.2174	27.73
	P	5.9186	0.2565**	29.2463	0.0089	0.8921	33.48
	A	5.4207	0.0484***	4.9545	0.0025	0.2476	84.68
Mahasamund	Y	6.5037	0.2914**	33.8361	-0.0103	-1.0277	34.06
	P	4.9740	0.3500***	41.9125	-0.0027	-0.2739	42.97
	A	4.7741	0.0725**	7.5243	0.0347**	3.5273	66.29
Dhamatari	Y	6.4899	0.3132***	36.7832	0.1031	10.8637	67.81
	P	4.3155	0.3954***	48.4947	0.1425*	15.3143	78.80
	A	6.0104	0.0357***	3.6387	0.0073	0.7311	74.28
Durg	Y	6.4996	0.2307*	25.9451	0.0500	5.1258	22.47
	P	5.5593	0.2767*	31.8794	0.0624	6.4408	29.91
	A	5.4473	0.0461***	4.7221	0.0095	0.9499	98.29
Rajnandgaon	Y	6.6367	0.1216	12.9260	0.0568	5.8446	20.74
	P	5.1335	0.1779*	19.4747	0.0714	7.3984	34.10
	A	4.4443	0.0327***	3.3265	0.0070	0.7068	81.14
Kawardha	Y	6.4490	0.1741*	19.0124	0.0630	6.5022	34.05
	P	3.9426	0.2171**	24.2486	0.0752	7.8101	46.43
	A	5.7377	0.0101	1.0188	0.0047	0.4690	24.45
Bilaspur	Y	6.7101	0.2223**	24.9005	0.0107	1.0741	30.51
	P	5.4971	0.2428**	27.4786	0.0205	2.0735	33.86
	A	5.5466	0.0200	2.0161	-0.0041	-0.4088	10.50
Janjgir	Y	6.3049	0.3836***	46.7491	0.1106	11.6921	76.44
	P	4.9012	0.4137***	51.2461	0.1116	11.8057	78.61
	A	4.6951	0.0002	0.0167	0.0004	0.0375	0.35
Korba	Y	6.6545	0.1293	13.8082	0.0174	1.7575	18.03
	P	4.3995	0.1396*	14.9867	0.0229	2.3126	21.67
	A	5.4858	0.0009	0.0905	-0.0011	-0.1119	7.58
Raigarh	Y	6.6845	0.1868**	20.5432	-0.0027	-0.2667	28.96
	P	5.2200	0.1980**	21.8935	0.0013	0.1326	32.66
	A	7.8156	0.0274***	2.7805	0.0059	0.5885	77.55
Plain Zone	Y	6.5274	0.2517***	28.6167	0.0412	4.2032	44.51
	P	7.4353	0.2791***	32.1929	0.0470	4.8164	49.35

***, **, *significant at 1%, 5% and 10% level of significance respectively

@ % r1& r_2 indicate the partial compound growth rates (in percentage) corresponding to bp (partial linear regression coefficient corresponding to periodic effect variable 'P') and bt (partial linear regression coefficient corresponding to time variable 'T') respectively.

Table.2 Production function as influenced by the area and productivity of rice in C.G. Plainand its constituent districts for period1998-99 to 2012-13

Districts/Region	Production Function								(1)*	(2)$	(3)@
Raipur	ln P (A, Y) =	-32.0674	+	5.5665	ln A	+	0.0747	ln Y	68.104	2.279	70.383
Mahasamund	ln P (A, Y) =	-14.1231	+	3.1386	ln A	+	0.0146	ln Y	77.991	0.097	78.088
Dhamatari	ln P (A, Y) =	-1.9607	+	0.6784	ln A	+	0.2523	ln Y	56.311	21.312	77.623
Durg	ln P (A, Y) =	-19.0547	+	3.6109	ln A	+	0.0471	ln Y	77.296	1.340	78.636
Rajnandgaon	ln P (A, Y) =	-18.2530	+	3.8774	ln A	-	0.0023	ln Y	98.897	0.001	98.898
Kawardha	ln P (A, Y) =	-16.2157	+	4.0886	ln A	+	0.1447	ln Y	84.409	6.135	90.544
Bilaspur	ln P (A, Y) =	-7.0703	+	1.5655	ln A	+	0.1884	ln Y	20.537	9.947	30.484
Jajgir	ln P (A, Y) =	0.2527	+	0.1058	ln A	+	0.3346	ln Y	4.763	69.553	74.316
Korba	ln P (A, Y) =	-5.0107	+	1.4056	ln A	+	0.2483	ln Y	0.421	16.291	16.711
Raigarh	ln P (A, Y) =	-11.1400	+	2.2756	ln A	+	0.2808	ln Y	0.144	25.455	25.599
Plain Zone	ln P (A, Y) =	-31.9541	+	4.3904	ln A	+	0.0898	ln Y	76.452	2.017	78.469

* percent sum of squares explained by ln A, i.e. area effect

$ percent sum of squares explained by ln Y, i.e. yield effect

@ Total percent sum of squares explained by ln P(A, Y) i.e. by the model (3)

Table.3 Prediction of area, yield and production under rice for Chhattisgarh plain and its constituent district for the period 2008-09 to 2015-16*

District/region		YEAR								% Increase/Decrease
		2008-09**	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	
	A@	527.87	531.02	534.2	537.39	540.61	537.99	541.2	544.44	3.14
	Y	1545	1542	1538	1535	1532	1940	1935	1931	24.98
Raipur	P	810.1	817.32	824.61	831.97	839.39	1047.02	1056.36	1065.78	31.56
	A	261.96	262.61	263.26	263.91	264.57	274.94	275.62	276.31	5.48
	Y	1584	1568	1552	1536	1520	2120	2098	2077	31.12
Mahasamund	P	412.14	411.01	409.88	408.76	407.64	584.88	583.27	581.68	41.14
	A	152.38	157.75	163.32	169.08	175.04	163.85	169.62	175.61	15.24
	Y	1868	2071	2296	2546	2822	2555	2833	3141	68.15
Dhamtari	P	282.64	325.92	375.83	433.39	499.76	419.7	483.98	558.09	97.46
	A	457.08	460.43	463.79	467.18	470.6	473.72	477.18	480.67	5.16
	Y	1396	1468	1543	1622	1705	1759	1849	1943	39.18
Durg	P	633.88	674.7	718.16	764.42	813.65	835.95	889.8	947.11	49.41
	A	269.12	271.67	274.26	276.86	279.49	281.83	284.5	287.21	6.72
	Y	1162	1230	1302	1378	1459	1313	1389	1470	26.51
Rajnandgaon	P	310.66	333.64	358.32	384.83	413.3	371.15	398.61	428.11	37.81
	A	94.59	95.26	95.93	96.61	97.29	97.74	98.43	99.12	4.79
	Y	1135	1209	1287	1371	1460	1351	1438	1532	34.98
Kawardha	P	106.6	114.93	123.9	133.58	144.01	132.45	142.8	153.95	44.42
	A	321.43	322.93	324.45	325.97	327.5	324.7	326.22	327.75	1.97
	Y	1616	1633	1651	1669	1687	2019	2040	2062	27.60
Bilaspur	P	515.9	526.6	537.52	548.67	560.04	657.67	671.3	685.22	32.82
	A	271.07	269.96	268.86	267.76	266.66	276.54	275.4	274.28	1.18
	Y	1932	2158	2410	2692	3006	2835	3166	3536	83.02
Janjgir	P	520.07	581.47	650.12	726.87	812.68	786.59	879.45	983.28	89.07
	A	109.5	109.54	109.58	109.62	109.67	109.52	109.56	109.6	0.09
	Y	1164	1185	1206	1227	1248	1325	1348	1372	17.87
Korba	P	126.64	129.57	132.56	135.63	138.77	145.62	148.99	152.43	20.36
	A	241.63	241.36	241.09	240.82	240.55	241.85	241.58	241.31	-0.13
	Y	1397	1394	1390	1386	1383	1684	1680	1676	19.97
Raigarh	P	335.36	335.81	336.25	336.7	337.15	408.79	409.33	409.87	22.22
	A	2707.49	2723.43	2739.45	2755.57	2771.79	2782.77	2799.15	2815.62	3.99
	Y	1516	1579	1646	1715	1787	1949	2031	2117	39.64
Plain Zone	P	4103.47	4301.1	4508.26	4725.4	4952.99	5424.49	5685.75	5959.6	45.23

* predicted value = exp (lnt + bp P + bt T), where lnt = intercept; bp and bt the partial regression coefficient corresponding to P and T cariables respectively.
** For 2008-09 to 2012-13, T= 1 to 5 for fixed P=3; and for 2013-14 to 2015-16 T= 1 to 5 for fixed P= 4.
@ A: area in 000' ha, Y: productivity in kg/ha, P: production in 000' tones

These column (1) and (2) showed that in most of the district's the productivity influence the area of rice by more than 56% barring the districts Bilaspur, Jangrir, Korba and Raigarh. For the district Janjgir, Korba and Raigarh the productivity was influenced by the production and only a little contribution is made by the area.

Prediction of area, yield and production for 2008-09 to2015-16

Table 3 gives a prediction of area, production and productivity of rice crop for the present year (2013-14), back five years (2008-09 to 2012-13) and future two years (2014-15 to 2015-16) based on the prediction models estimated in the present study (Table 1). It is expected that the productivity of rice in Chhattisgarh plain will increase from 1516 to 2117 kg/ha, {[(2117-1516)/1516)]100 = 39.64%}, by the turn of this decade, if the present growth trend in productivity is maintained. Since the increasing in area is going to be {[(2815.62-2707.49)/2707.49]100 = 3.99%}, the 39.64% rate of increases in productivity. It is therefore, necessary that special effort should be made to identification

major constraints and gaps in technologies, So that the adaptation of improved technologies may be made more effective and which may ultimately result in improving the productivity at a much faster rate than the existing rate. Similarly other predictions for different districts may be obtained from the estimated models presented in table 1.

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