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Predictive models and production function for area, production and productivity of chilli crop in different agro climatic zones of Chhattisgarh

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Abstract
Chhattisgarh State has three agro-climatic zones. The Chhattisgarh Plains, the Bastar Plateau, and the Northern Hills Region. The current study aims to investigate the predictive models and production function for area, production, and productivity of Chilli crops in different agro-climatic zones of Chhattisgarh. The parameters in the estimated prediction model for the area, production, and productivity of the chilli crop for the various agro climatic zones in Chhattisgarh of the 33 districts in the state, only 17 are being studied because secondary data from 2004-05 to 2021-22 are available and were used for the studies. In addition to the trend effect in the time-series data, the predictive model under investigation had the special feature of a structural periodic effect as a factor to capture any cyclic pattern. The acreage, productivity, and production of the chilli crop were assessed for this periodic effect. As an alternative to this model, which serves as the first case and assumes a 3-year periodic cyclic effect along with an annual effect operating within it as a nested effect, another model has also been assumed, for comparison purposes, that combines an overall periodic effect variable with an overall trend effect variable without any nesting. In order to comprehend the impact of an influencing factor-either productivity or area-on the output of chillies, the impacts of crop productivity and area were also determined.

Keywords: Predictive models, climatic zones, chilli crop, production, and productivity

Introduction
India is often called “The Home of Spice” because it produces an incredible variety of spices unmatched by any other country. The country's diverse climate allows it to grow nearly all types of spices. These spices are essential in cooking, adding unique flavors and aromas to dishes. They're a crucial part of agriculture and play a significant role in culinary traditions around the world.

In Chhattisgarh state, there are 67756 hectares of spice growing, with a 449,353 metric ton annual production. Turmeric has the most production, at 106,430 metric tons, followed by coriander at 66, 299 metric tons and chilli at 66,290 metric tons. The three crops with the largest cultivation areas are coriander (14,988 ha), turmeric (12,072 ha), and chilli (10,348 ha) (Directorate of Horticulture, Raipur, 2021).

The total geographical area of Chhattisgarh is 13.79 million hectares. Out of which the net sown area is only 4.77 million hectares, which is 35.44 per cent of total geographical area. Chhattisgarh, a state in central India, is known for its cultivation of chili peppers. The region's conducive climate and soil conditions make it suitable for growing various types of chili peppers. Farmers in Chhattisgarh cultivate both indigenous and hybrid varieties of chilies.

Predictive model proposed by Singh and Baghel (1991-94) has been fitted separately for area, production and productivity for different Agro climatic zones of Chhattisgarh addition to assessment of their growth rates. Predictions were also made for the next 8 years wherever model diagnostics permitted.

Apart from above a production function was also estimated to understand the influences of area and productivity on the production of the chilli crop in the entire different Agro climatic zones of Chhattisgarh during this period.

The study during period at from 2004-05 to 2021-2022. 17 districts of the state of Chhattisgarh, Raipur, Mahasamund, Dhamtrai, Durg, Rajnandgaon, Kabirdham, Bilsapur, Dantewada, Kanker, Jagdalpur, Raigarh, Janjgir, Korba, Jaspur, Sarguja, Korea, and Baster, were taken for the study.
Thus, the objective of present study is (i) to assess growth rate of area, production and productivity of Chilli Crop in different Agro climatic zones of Chhattisgarh (ii) and to develop predictive model for area, production and productivity of Chilli Crop in different Agro climatic zones of Chhattisgarh and (iii) to assess the influencing factor (area and productivity) on production of Chilli Crops in different Agro climatic zones of Chhattisgarh.

Materials and Methods

Prediction model

The required time series data for the study were collected from the website https://agriportal.cg.nic.in/PortHi/ (2004-05 to 2021-22).
During analyses it was realized that a three year periodic effect is working on the response variable in most of the district/regions. Therefore, this periodic effect was considered as a structural effect changing every three years the area, production and productivity scenario of chilli crop. 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. The following multiple regression models was fitted in all cases using stepwise regression technique.

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

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

Where, $\widehat{ln}Y$ = expected value of the natural logarithm of the response
Variable Y may be area, productivity or production of a given district/ region.

lnt = intercept
P= periodic time Variable.
T = annual time variable
B_p = partial linear regression coefficient corresponding to variable P
b_t = partial linear regression coefficient corresponding to variable T
ϵ = error/disturbance component normally distributed with mean zero and common variance.
Let T be fixed at a particular position in any period, i.e. at 1st, 2nd or 3rd etc. so that it may be considered constant within any period while P varies. Then we may write (1b) in the form

$\widehat{ln}$Y= C+ bp P, where C = lnt (Since bt= 0 for constant T) (2a)

Or, $Y_x = a\ e^{\theta X}$ where Y_x = Y, a= e^c, θ= bp, x=P (2b)

Again, on putting x= 0 and 1 respectively in equation (2b), we get Y_0 = a and $Y_1 = a\ e^{\theta} = Y_0(1+r_1)$, where$(1+r_1) = e^{\theta}$, say. Then, we have % $r_1 = \{(Y_p - Y_{p-1})/Y_{p-1}\}$ 100 for fixed T. Also, $r_1 = e^{\theta} - 1 = 1 + \theta - 1 = \theta$ = bp (higher powers of θ in e^{θ} may be ignored). Therefore, r_1 may be defined as the proportional rate of growth in response variable Y per unit change of P for fixed T, i.e., a partial compound growth rate. Similarly r_2 and b_t can be interpreted with respected to variable T.
Lastly, our interest is to find the extent of influence of area and productivity on the production of Chilli corp. 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 component by ε N $(0,\sigma_{\varepsilon}^2)$ and then introducing the intercept term we can have the following linear statistical model.

$$P(A, Y) = c0 + c1 \ln A + c2 \ln Y + \varepsilon \quad (3a)$$

$$\text{Or, } P(A, Y) = c0 + c1 \ln A + c2 \ln Y \quad (3b)$$

$$\text{Or, } (A, Y) = d0\ Ac1\ Yc2,\ d0 = ec0 \quad (3c)$$

Where A, Y and $\hat{P}$ (A, P) denoted 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

Predictive model and partial growth rates for area, production and productivity of chilli crop

The results of a compound growth analysis of the spice crops chilli, for the growing seasons of 2004-05 to 2021-22 in the agro climatic zones of various districts in Chhattisgarh are shown in this section. The predictive model-1 and model-2 along with their estimated regression coefficients for periodic and annual effects/growth rates for area and production are shown in Table-1. Thus, it is evident from Table-1, that the estimated predictive models as defined in equations 1(a) and 1(b) for area, production and productivity under chilli crop in different district of Chhattisgarh For the area It was observed from the Table-1, partial compound growth rate for area in Rajnandgaon (-78.158 percent), Kabirdham (-68.246%), Jagdalpur (-83.061%), Raigarh (-64.581%), Jaspur (-77.015%), Korea (-79.485%), Baster (-68.622%) respectively and statistically significant at 1 percent level, whereas, Kanker (-130.914%), Janjgir (-96.403%) found statistically significant at 5 percent level, Durg (-128.466%), found statistically significant at 10 percent level, and remaining Districts are found non- significant. the Annual partial compound growth rate of area Korea (0.070%) was found statistically significant at 10 percent level and remaining all districts were found statistically non-significant. In Case of Production under Chilli we find that the partial compound growth rate in Mahasamund (-22.940%), Rajnandgaon (-38.093%), Jagdalpur (-64.441%), Janjgir (-126.919%), Raigarh (-35.247%), Jaspur (-44.683%) found statistically significant at 1 percent level. Whereas Kabirdham (-74.180 percent), Kanker (-81.914%), Korea (-68.622%) found statistically significant at 5 percent level, and non-significant in remaining Districts. Annual partial compound growth rate for Production of the constituents districts were found statistically non- significant results. For the yield of Chilli the partial compound growth rate in Mahasamund (-36.524%),

Rajnandgaon (-58.445%), Jagdalpur (-80.999%), Janjgir (-130.516%), Raigarh (-68.902%), Jaspur (-64.345%), Baster (-117.003%) found statistically significant at 1 percent level, whereas found statistically non-significant at 5 percent level, and Dantewada (77.667%) found statistically significant at 10 percent level. and remaining Districts are found non-significant. the Annual partial compound growth rate of yield in Korba (-107.431%) found statistically significant at 10 percent level. Raipur, Mahasamund, Dhamtrai, Durg, Rajnandgaon, Kabirdham, Bilsapur, Dantewada,Kanker, Jagdalpur, Raigarh, Janjgir, Jaspur, Sarguja, Korea, Baster had registered non-significant.

Table 1: Prediction models of area, productivity and production under Chilli in Chhattisgarh for period (2004-05 to 2021-22)

Districts/Region		LNT	BP	%r_1 @	Bt	% r_2 @	% R^2
Raipur	A	0.034	-0.130	-113.019	0.058	-94.216	9.813
	Y	8.191	0.006	-99.371	-0.061	-106.068	0.343
	P	1.317	-0.124	-112.390	-0.003	-100.284	2.651
Mahasmund	A	-1.023	0.136	-86.415	0.150	-84.977	11.418
	Y	5.904	0.635***	-36.524***	0.138	-86.161	75.036***
	P	-2.026	0.771***	-22.940***	0.289	-71.138	59.47***
Dhamtari	A	-1.234	0.049	-95.073	0.313	-68.731	11.898
	Y	8.321	0.106	-89.352	0.012	-98.832	9.805
	P	0.179	0.156	-84.425	0.324	-67.563	9.103
Durg	A	1.266	-0.285*	-128.466*	0.085	-91.528	21.348**
	Y	7.654	0.061	-93.927	0.036	-96.442	6.949
	P	2.012	-0.224	-122.393	0.120	-87.970	11.85
Rajnandgaon	A	-0.468	0.218***	-78.158***	0.080	-91.985	84.623***
	Y	6.837	0.416***	-58.445***	0.046	-95.411	52.867***
	P	-0.476	0.619***	-38.093***	0.112	-88.817	62.74
Kabirdham	A	-0.734	0.318***	-68.246***	0.087	-91.266	48.641***
	Y	9.443	-0.059	-105.934	-0.065	-106.519	3.752
	P	1.801	0.258**	-74.180**	0.022	-97.785	29.10**
Jagdalpur	A	-0.764	0.169***	-83.061***	0.079	-92.080	50.610***
	Y	8.203	0.190***	-80.999***	0.055	-94.546	91.072
	P	0.552	0.356***	-64.441***	0.128	-87.211	82.70***
Kanker	A	-0.053	-0.309**	-130.914**	0.038	-96.153	34.590**
	Y	6.357	0.490	-51.000	0.159	-84.074	35.863
	P	-0.604	0.181**	-81.914**	0.198	-80.227	4.201*
Dantewada	A	-0.647	-0.085	-108.462	-0.003	-100.254	7.221
	Y	7.054	0.223*	-77.667*	0.147	-85.263	18.215*
	P	-0.501	0.139	-86.130	0.145	-85.517	4.501
Bilaspur	A	0.976	-0.022	-102.178	-0.042	-104.214	0.438
	Y	8.683	0.120	-87.974	-0.270	-127.003	24.716
	P	2.751	0.098	-90.152	-0.312	-131.218	6.820
Janjgir	A	-0.205	0.036**	-96.403**	0.035	-96.487	30.326**
	Y	9.438	-0.305***	-130.516***	0.111	-88.909	52.093***
	P	2.326	-0.269***	-126.919***	0.146	-85.397	48.20***
Korba	A	0.037	0.063	-93.651	0.050	-94.963	4.939
	Y	9.576	-0.074	-107.431	-0.199*	-119.873*	26.739*
	P	2.705	-0.011	-101.082	-0.148	-114.835	5.458
Raigarh	A	-0.400	0.354***	-64.581***	0.129	-87.142	84.751***
	Y	7.217	0.311***	-68.902***	0.071	-92.864	55.579***
	P	-0.034	0.648***	-35.247***	0.193	-80.747	72.53
Jaspur	A	-0.541	0.230***	-77.015***	0.052	-94.827	77.502***
	Y	7.052	0.357***	-64.345***	0.069	-93.090	53.272***
	P	-0.288	0.553***	-44.683***	0.104	-89.609	63.20
Sarguja	A	1.477	-0.185	-118.474	-0.105	-110.481	11.250
	Y	9.067	-0.120	-111.996	0.040	-95.968	7.193
	P	3.636	-0.305	-130.470	-0.064	-106.448	12.20
Korea	A	-0.581	0.205***	-79.485***	0.070*	-93.035*	89.762
	Y	6.543	0.181	-81.891	0.596	-40.434	22.003
	P	-0.946	0.386**	-61.375**	0.665	-33.470	40.50**
Baster	A	-1.021	0.314***	-68.622***	0.102	-89.773	69.535***
	Y	9.276	-0.170***	-117.003***	-0.034	-103.403	49.437***
	P	2.327	-0.020	-102.031	0.000	-99.981	4.051

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

@ r1 & @ r2 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.

A: Area in 000' ha, Y: Yield in Kg/ha, P: Production in 000' tones

Prediction of area and production for next 8 years

The prediction of area and production of chilli crop at different agro climatic zones of Chhattisgarh is given on the Table-2. As per the predicted result there is a slight increase in the area of the production. The average increment in area of Raipur of 8 years is 0.603 ha and the average production is 1.905 tons in 2022-23 to 2029-30 year. As per of Mahasmund is 1.126 ha and 19.307 tones as per of Dhamtari is 0.937 ha and 7.040 tons. Followed by the Durg is 0.979 ha and 3.152 tone and of Rajnandgaon is 2.511 ha and 24.157 tone. As per of Kabirham is 3.372 ha and 24.755 tone. As per of Jagdalpur is 1.429 ha and 16.766 tone. Followed by Kanker is 0.202 ha and 2.504 tone. As per of Dantewada is 0.329 ha and 1.901 tone. As per of Bilaspur is 2.115 ha and 12.742 tone. As per of janjgir is 1.085 ha and 3.669 tone. As per of Korba is 1.663 ha and 9.733 tone. Followed by Raigarh is 6.419 ha and 54.910 tone. As per of Jaspur is 2.311 ha and 35.340 tone. As per of sarguja is 1.241 ha and 6.287 tone. As per of Korea is 2.035 ha and 24.883 tone and Followed by Baster is 2.579 ha and 9.203 tone.

Table 2: Prediction of area, production and productivity under chilli crop for different District of Chhattisgarh for Period (2022-23 to 2029-30)

Districts		2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Raipur	A	0.572	0.607	0.643	0.681	0.702	0.723	0.733	0.864
	Y	3498.187	3291.175	3096.414	2913.178	2840.786	2719.239	2710.982	2615.048
	P	2.002	1.996	1.990	1.984	1.978	1.768	1.763	1.758
Mahasmund	A	0.824	0.958	1.113	1.293	1.502	1.751	1.878	1.975
	Y	10066.819	11556.462	13266.535	15229.658	17483.275	18996.309	21807.299	25034.246
	P	8.314	11.101	14.820	19.787	26.417	27.975	29.999	32.040
Dhamtari	A	0.509	0.696	0.951	1.301	1.779	1.834	1.931	1.999
	Y	7065.648	7150.946	7237.275	7324.645	7413.070	7855.742	7950.579	8046.560
	P	3.607	4.988	6.896	9.535	13.184	14.216	15.830	18.061
Durg	A	0.929	1.011	1.101	1.198	1.305	1.498	1.760	1.828
	Y	2966.090	3074.815	3187.525	3304.366	3425.491	3552.654	3668.217	3788.017
	P	2.751	3.102	3.497	3.943	4.446	5.199	5.479	6.795
Rajnandgaon	A	2.018	2.186	2.368	2.565	2.779	2.809	2.818	2.945
	Y	7808.749	8176.341	8561.237	8964.252	9386.239	11837.172	12394.400	12977.859
	P	15.348	17.167	19.202	21.477	24.023	28.503	31.881	35.659
Kabirdham	A	2.568	2.801	3.056	3.333	3.636	3.529	3.850	4.200
	Y	8804.339	8250.260	7731.050	7244.516	6788.600	6699.910	6577.576	6588.113
	P	21.607	22.087	22.579	23.081	23.594	24.243	24.361	24.991
Jagdalpur	A	1.174	1.270	1.374	1.487	1.610	1.790	1.804	1.927
	Y	9976.624	10540.708	11136.686	11766.361	12431.639	12064.228	12746.347	13467.033
	P	11.705	13.303	15.120	17.184	19.531	19.710	20.992	21.585
Kanker	A	0.210	0.218	0.227	0.236	0.245	0.154	0.160	0.166
	Y	7832.210	9181.997	10764.404	12619.519	14794.341	15784.643	15987.923	17570.910
	P	1.647	2.008	2.447	2.983	3.316	3.474	3.506	3.933
Dantewada	A	0.341	0.340	0.339	0.338	0.337	0.313	0.313	0.312
	Y	4088.772	4736.245	5486.249	6355.018	7361.360	5110.232	5919.457	6856.826
	P	1.404	1.623	1.876	2.168	2.507	2.613	2.865	2.955
Bilaspur	A	2.280	2.186	2.096	2.010	1.927	1.830	1.538	1.050
	Y	8209.112	6266.668	4783.846	3651.890	2787.778	2455.748	2465.648	2393.771
	P	18.709	13.695	10.024	7.338	5.635	5.371	4.105	4.056
Janjgir	A	1.010	1.046	1.083	1.122	1.162	1.247	1.284	1.223
	Y	3053.366	3411.816	3812.346	4259.896	4759.986	4850.708	4874.929	4890.969
	P	3.086	3.572	4.133	4.783	5.534	6.358	6.729	7.158
Korba	A	1.495	1.571	1.652	1.737	1.826	1.892	1.974	1.989
	Y	8160.005	6687.531	5480.765	4491.761	3681.222	3577.965	3210.521	3089.831
	P	12.207	10.528	9.079	7.830	6.753	6.073	5.412	5.980
Raigarh	A	4.477	5.094	5.795	6.593	7.101	7.579	7.757	8.256
	Y	6925.739	7435.343	7982.445	8569.803	9200.379	9452.174	10147.676	10894.355
	P	29.934	36.307	44.036	53.410	64.780	67.226	69.408	84.184
Jaspur	A	1.937	2.040	2.149	2.264	2.385	2.438	2.568	2.705
	Y	7376.098	7903.018	8467.580	9072.472	9720.574	10540.708	11293.696	12100.475
	P	23.500	26.076	28.933	32.105	35.623	40.854	45.331	50.300
Sarguja	A	1.564	1.408	1.267	1.141	1.027	1.030	1.070	1.053
	Y	4949.293	5151.277	5361.505	5580.312	5808.049	5889.629	5968.373	5985.628
	P	7.745	7.265	6.814	6.392	5.995	5.709	5.355	5.023
Korea	A	1.672	1.793	1.923	2.063	2.212	2.052	2.201	2.361
	Y	3115.048	4653.330	5259.917	75620.157	76792.697	79733.121	79775.236	80295.640
	P	5.202	10.115	19.668	38.245	74.366	7.652	14.880	28.933
Baster	A	1.917	2.123	2.351	2.604	2.813	2.825	2.907	3.219
	Y	4411.632	4264.158	4121.614	3983.834	3850.661	3721.939	3597.520	3477.260
	P	9.272	9.272	9.272	9.272	9.272	9.088	9.088	9.088

Table 3: Productions function as influenced by the area and productivity under chilli crop for Chhattisgarh and its constituent districts for period (2004-05 to 2021-22).

Districts		Production Function			(1)*	(2)$	(3)@
		Lnt.	lnA	lnY			
Raipur	ln P (A, Y) =	-6.9078	1.0000	1.0000	55.795	40.205	96.000
Mahasamund	ln P (A, Y) =	-6.9078	1.0000	1.0000	52.812	42.288	95.100
Dhamatari	ln P (A, Y) =	-6.9078	1.0000	1.0000	86.563	11.437	98.000
Durg	ln P (A, Y) =	-4.9301	1.0531	0.7427	72.086	25.814	97.900
Rajnandgaon	ln P (A, Y) =	-7.4428	0.8130	1.0748	81.096	15.514	96.610
Kabirdham	ln P (A, Y) =	-6.9021	0.9922	1.0016	49.321	46.991	96.312
Jagdalpur	ln P (A, Y) =	-7.1549	0.9883	1.0280	79.043	17.763	96.806
Kanker	ln P (A, Y) =	-6.7887	1.0149	0.9782	30.749	65.663	96.412
Dantewada	ln P (A, Y) =	-7.0644	0.9878	1.0102	49.446	46.231	95.678
Bilaspur	ln P (A, Y) =	-6.8863	1.0308	0.9928	76.877	20.880	97.757
Janjgir	ln P (A, Y) =	-6.8866	0.9949	0.9976	8.719	89.279	97.998
Korba	ln P (A, Y) =	-7.0705	1.0225	1.0163	44.957	50.555	95.512
Raigarh	ln P (A, Y) =	-8.4863	0.7524	1.2217	73.745	15.330	89.075
Jaspur	ln P (A, Y) =	-7.3094	0.8493	1.0520	72.375	20.102	92.477
Sarguja	ln P (A, Y) =	-7.6470	1.0148	1.0798	69.601	25.793	95.394
Korea	ln P (A, Y) =	-6.9430	1.0076	1.0067	16.426	79.085	95.511
Baster	ln P (A, Y) =	-7.3630	0.5488	1.1000	26.885	51.447	78.332

Production function

To know the extent of influence of area and productivity on the production of Chilli crop the postulated production function is given by equations 3(a), 3(b) and 3(c). The estimated production in terms of area and yield for the period (2004-05 to 2021-22) have been presented in Table-3 respectively, in all districts the production function satisfactorily fits to the data as indicated by more than 70 percent. The model showed highest R^2 up to 98.0 percent for Dhamatari district. The column designated (1) and (2) gives the breakup of the total percent sum of squares explained by the production component, In P (A, Y) into its percent sum of square explained by the area component, In A and the yield component In Y and showed that in Rajnandgaon, jagdalpur, Raigarh and Jaspur districts the area influences the production by more than 72 percent. For Korea and Janjgir district the production was influenced by the productivity and only a little contribution is made by the area.

Conclusion

It can be concluded from the present study that the estimated predictive models for area and production under Chilli crop in different agro-climatic zones of Chhattisgarh were significant for both models 1 and 2. For the area under chilli in Rajnandgaon, Kabirdham, Jagdalpur, Raigarh, Jaspur, Korea, and Baster, respectively, and statistically significant at 1 percent level, Kanker and Janjgir were found statistically significant at 5 percent level. Annual partial compound growth rate of area in Korea was found statistically significant at 10 percent level and remaining all districts were found statistically non-significant. For Production the partial compound growth rate in Chilli found statistically significant Kabirdham, Kanker, Korea at 5 percent level. Annual partial compound growth rate for Production of the constituents districts were found statistically non- significant results. For the Chilli crop in all districts the production function satisfactorily fits to the data as indicated by more than 70 percent. The model showed highest R^2 up to 98.0 percent for Dhamatari district. In Rajnandgaon, Jagdalpur, Raigarh and Jaspur districts the area influences the production by more than 72 percent. For Korea, Janjgir district the production was influenced by the productivity and only a little contribution is made by the area.

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