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A Mathematical Analysis of Compromising Programming Techniques

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Abstract: *Agriculture is the back bone of Indian economy and provides livelihood to about 70 percent of the population and about one third of our national income gets generated in this sector. After independence, in early years, there was a problem of a food shortage. The position at the food front became a matter of concern in the early sixties. To meet the situation efforts were made to develop the agriculture sector of the economy. Toward the mid of sixties the new agriculture technology emphasizing the use of fertilizer and irrigation, ushered an era popularly could as green revaluation. However it was confined to few states and few crops. In present state, the nation's objective is not only to increase the food grain production but also to increase the employment ventures. While individual farmer may be interested in maximizing his cash income risks aversion etc. The mathematical programming approach to the modeling of agricultural decisions rests on certain basic assumptions about the situation being modeled and the decision maker himself. One fundamental assumption is that the decision maker (DM) seeks to optimize a well defined single objective. In reality this is not the case, as the DM is usually seeking an optimal compromise amongst several objectives, many of which can be in conflict, or trying to achieve satisfying levels of his goals. For instance, a subsistence farmer may be interested in securing adequate food supplies for the family, maximizing cash income, increasing leisure, avoiding risk etc. but not necessarily in that order. Similarly a commercial farmer may wish to maximize gross margin, minimize his indebtedness, acquire more land, reduce fixed costs etc.*

Key-words: *Decision Making, Optimization, Mathematical programming, Minimization & maximization.*

I. Introduction

The commonly used traditional mathematical programming approach to the modeling of agricultural decision based on the assumption that the decision maker/planner seeks to optimize a well defined single objective for explicit economic analysis. However, in reality this is not the case as the decision maker is usually seeking an optimum compromise amongst several objectives, may of which may be in conflict despite the recognition giving to the existence of multiple dimensional objectives in farm planning, very little work seem to have been done by agricultural economists to develop and use methodologies that model. The multidimensional decision situations realistically. Several approaches to deal with the multiple criteria decision making problems, compromise programming is the one which can be applied to a wide range of problems. The focus of the present study was to examine food grain production performance/ potential within the existing resources at existing level of technology and at improved level of technology, using compromise programming techniques. Multiple objectives are Maximization of Gross returns, Maximization of grain production, maximization of human labour use & minimum risk in production by using compromise programming techniques

II. Problem Definition

To achieve the objectives of the study ten largest food grain producing states were selected on the individual basis of each crop (All those states were selected whose contribution was minimum 5% to total food grain's area and production). The selected states were Andhra Pradesh, Bihar, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Uttar Pradesh and West Bengal. Which covered the 90 percent of foodgrain production and 86 percent of total food grain area of India in the average of trinneum (1996-99). State wise secondary data on different input variables and for cost of cultivation for all foodgrain crops for the period 1980-81 to 2009-10 were collected from statistical Abstract of India, Statistical Abstract of Punjab, Agricultural Statistics at a glance and the Reports of the commission for agricultural costs and prices. For the improved level of Technology data published in "50 years of front line" Agricultural extension programmes (I.C.A.R.) and from Annual reports of National Demonstration projects were collected.

To obtain the optimum production plans multiple objective programming techniques were used. For obtaining the risk coefficients, the present study used the time series data of the returns for each crop from the period 1986-87 to 2009-10. Further five sets of weights allotted to the different objectives were used resulted in ten compromise farm plans for each state separately.

III. Area Of The Study

The present investigation was taken up for India as a whole, ten large food grain producing states were selected on the individual basis of each crop to their contribution to total food grain production and area under food grains. All those states whose contribution was more than 5 percent to total food grain or individual crop wise were selected on the basis of average of triennium (2007-2010). The selected states were Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Andhra Pradesh, Karnataka, Rajasthan, Bihar, Maharashtra, Uttar Pradesh and West Bengal covered the 90 percent of food grains production and 88 percent of total food grain area of India. The present study is primarily based on secondary data. Keeping in view the objectives of the study, state-wise secondary data on different variables such as area, production and yield. Food grain crops for the period 1990-91 to 2009-2010 were collected from Statistical Abstract of India, Statistical Abstract of Punjab, Fertilizer Statistics, Agricultural Statistics at a Glance, and the Reports of the Commission for Agricultural Costs and Prices published by Ministry of Agriculture, Government of India.

IV. Analytical Procedure

An order to examine the performance of food grain production in India state wise tabular analysis was done to see the relative performance. Ranks were assigned to each state on the basis of their contribution to total area and production of food grains in India for two terminal point of times. The compound growth rates were computed for area, production, yield and for resource use for different states of India by fitting the exponential trend equation i.e.

$Y = ab^t$

$\text{Log } Y = \log a + b \log t$

$b = (1+r)$

$r = (b-1) \times 100$

where

Y = study variable

a = constant

b = regression coefficient

t = time

r = compound growth rate in percent

To test the significance of the compound growth rates, t-test applied was:

$t^* = r/s.e(r)$

Where t^* = calculated t-ratio

r = compound growth rate

S.E.(r) =standard error of the compound growth rate

V. Technique Of Analysis

The objective functions are optimized simultaneously in the multiple objective programming farm planning model. First, the pay-off matrix has been constructed using 'ideal point' which represents the optimum values of the objectives under consideration. In fact, this ideal point is not feasible because the objectives are in conflict; we select the efficient farm plans closest to it or best compromise by using compromise programming techniques. The worst element from each column of the pay-of matrix will be the 'anti-ideal point'. Among the different techniques to generate the efficient set, a variant of the weighting method has been chosen known as non-inferior set estimation (NiSE) method, as the most suitable multiple objective programming technique for generating the efficient set (cohan, church and steer, 1979). To obtain compromise solution from the efficient sets, the degree of closeness, dj between the jth objective and its ideal value has been calculated and It was made unit free by taking relative deviation as under:

$$\text{Min } L_1 = \Sigma \delta_j \frac{Z_j^* - Z_j(\underline{x})}{Z_j^* - Z^*_j} \quad \text{Subject to } (\underline{X}) \in \underline{F}$$

Where, Zj(x) = the jth objective function to be maximized/minimized

Zj* = the ideal value of the jth objective function

Z*j = the anti-ideal values of the jth objective function.

(x) a vector of the decision variables and

F = the set of all feasible farm plans.

The distance between each solution and its ideal point is obtained by following distance function:

$$Lp\ (\delta, K) = \left[\sum_{J=1}^{k} (\delta_j . d_j)^p \right]^{1/p}$$

Where, p = weights the deviations according to their magnitudes, K = no. of objective functions, δj = weights the importance of the deviations of jth objective from its ideal value, dj = degree of closeness between the jth objective and its ideal value.

For some value of δ and different values of P different compromise solution for distant function Lp were obtained and the farmer/nation can chose any one solution for a given preferences of the different objectives out of the various compromise solutions. However the distance function lp is usually used for P=1 and $P_2=\alpha$ which shows the A longest and the chebysew distance in the geometric sense respectively (greater weight is given to the largest deviation). Therefore, maximum of the individual deviations is minimized with p=α. For different values of P and δj, we can generate different compromise solutions. The alternate with the lowest value for the distance function will be the best compromise solution because it is the nearest solution swith respect to the ideal point.

For Lα matrix (P=α), the minimised by minimum of the individual deviation is minimized by solving the following linear programming model.

$$\text{Min } L_\alpha = d_\alpha$$

$$\text{Such that}$$

$$\delta_1 = \frac{Z_j^* - Z_j(x)}{Z_j^* - Z^*_j} \leq d_\alpha$$

$$\delta_2 = \frac{Z_j^* - Z_j(x)}{Z_j^* - Z^*_j} \leq d_\alpha$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\delta_k = \frac{Z_j^* - Z_j(x)}{Z_j^* - Z^*_j} \leq d_\alpha$$

$$(X) \in F$$

Where d = the largest deviation and k = number of objective functions.

L_1 and Lα matrix define a subset of the compromise sets. The other best compromise solution full between the solutions corresponding to L1 to Lα. For different sets of values of the weights δj the structure of the compromise sets can be modified.

The compromise programming approach find the optimum point for all the objectives and the compromise solutions for L1 and Lα formulate the bounds of the compromise set. Different set of the solution can be obtained by varying the weights given to the different objectives. Farmers can chooses any one solution for a given preferences of the different objectives out of the various compromise solutions.

VI. RESULTS

Existing food grain production and resource use has been studied for the two parts of time namely 1990-91 and 2009-10 and their intervening growth rates for the different study states. It deals with level of area, yield and production in 1990-91 and 2009-10 and their growth performance during this period for different foodgrain crops and selected states of India.

Table 1.1 Area and production levels of food grain crops and their growth from 1990-91 to 2009-10 in selected states of India

Area in 000 hectareProduction in 000 metric tones Yield in Kg./Hect.

	Rice			**Wheat**			**Maize**			**Barley**			**Jowar**		
States	1990-	2009-	C.G.R.	1990-	2009-	C.G.R.	1990-	2009-	C.G.R.	1990-	2009-	C.G.R.	1990-	2009-	C.G.R.
ANDHRA PRADESH															
Area	3824	4112	0.25NS	15.1	10.3	-1.10*	332	405	0.82*				2214	787	-5.7**
Rank	6	6		18	19		6	7					3	4	
Production	7868	11434	2.41**	5.9	6.9	1.25**	632	1348	4.19**				1334	547	-4.2**
Rank	1	3		19	18		5	2		NA			4	4	
Yield	2057	2780	2.03**	390	669	1.90NS	1903	3328	3.27**				602	695	1.45**
Rank	3	3		17	16		2	1					7	9	
BIHAR															
Area	5368	5099	-0.4NS	1640	2098	1.15**	851	685	-0.74*	106	42	-4.6**	10.1	2.7	-4.9**
Rank	2	4		5	6		3	4		5	4		20	21	
Production	4257	6632	2.35*	2202	4180	4.0**	769	1270	3.63**	80	42	-3.8**	5.8	2.5	-2.2*
Rank	4	5		6	6		3	3		6	6		16	17	

Yield	793	1300	2.78*	1342	1992	2.79**	903	1854	3.95**	754	1004	0.76NS	574	925	2.59**
Rank	14	15		7	7		12	8		8	6		9	4	
HARYANA															
Area	506	1083	3.94**	1562	2188	1.77**	74	21	-4.2**	135	36	-3.1*	118	129	-1.0NS
Rank	14	12		6	5		15	16		4	5		9	9	
Production	1250	2425	4.71**	3682	8568	4.54**	83	41	-2.9**	205	100	-2.1*	32	25	-0.05^{NS}
Rank	13	11		3	3		18	16		4	5		9	9	
Yield	2470	2239	0.65NS	2357	3915	2.70**	1122	1952	1.42*	1519	2778	1.45**	271	193	0.9NS
Rank	2	2		2	2		10	7		2	2		13	13	
KARNATAKA															
Area	1168	1425	1.39**	312	268	-1.0*	158	498	7.54**	NA			2114	1845	-0.32^{NS}
Rank	11	11		10	11		11	5					4	2	
Production	2364	3604	3.61**	180	219	0.40*	471	1618	9.1**				1792	1670	0.30NS
Rank	11	10		16	14		10	1					3	2	
Yield	2023	2529	2.18**	578	817	1.25NS	2981	3248	1.50**				847	905	0.55NS
Rank	4	4		16	15		1	2					3	5	
MADHYA PRADESH															
Area	4850	5305	0.55**	3306	4650	1.41**	788	849	0.51**	198	76	-2.1**	2252	808	-5.0**
Rank	4	3		2	2		4	3		3	3		2	3	
Production	3830	5373	2.19*	3313	8344	5.18**	770	1180	2.28*	236	109	-2.3**	1859	787	-4.0**
Rank	5	8		4	4		2	4		3	3		2	3	
Yield	789	1012	1.60*	1002	1794	3.70*	977	1389	1.69*	1191	1135	-0.3*	825	974	0.96**
Rank	17	17		10	8		11	13		4	5		2	3	
MAHARASHTRA															
Area	1515	1483	0.33NS	1128	1015	-1.9**	86	278	3.15**	9	1.5	-4.2*	6578	4775	-1.6**
Rank	9	10		7	7		14	9		8	8		1	1	
Production	2435	2467	1.27NS	989	1308	0.27NS	152	511	3.95**	7	1.2	-3.9**	4891	6483	0.85NS
Rank	10	12		8	9		17	9		8	8		1	1	
Yield	1607	1663	0.90NS	876	1288	2.11NS	1775	1837	0.80*	777	800	0.27NS	743	1357	2.39**
Rank	7	9		11	11		4	9		7	8		4	1	
PUNJAB															
Area	1270	2519	3.61**	2917	3338	0.73**	339	154	-3.8**	87	31	-3.9**	1.2	0.2	-0.5**
Rank	10	8		3	3		5	11		6	6		21	23	
Production	3755	7940	4.93**	8553	14460	3.24**	623	352	-3.4**	174	100	0.14Ns	0.8	0.2	0.5NS
Rank	6	4		2	2		6	10		5	4		18	19	
Yield	2956	3152	1.28**	2932	4331	2.46**	1837	2285	0.40**	2000	3225	3.95*	666	1000	1.03*
Rank	1	1		1	1		3	6		1	1		6	2	
RAJASTHAN															
Area	170	168	-0.5*	1768	2766	2.02**	918	946	0.37NS	410	216	-2.1**	904	535	-3.0**
Rank	20	21		4	4		2	1		2	2		5	5	
Production	150	205	0.75NS	2933	6879	4.99**	755	1024	1.64NS	521	426	-0.9NS	408	153	-4.3*
Rank	21	20		5	5		4	6		2	2		8	7	
Yield	881	1220	1.07*	1658	2486	2.85**	822	1082	1.05NS	1270	1976	1.20*	451	285	-1.2**
Rank	12	16		6	4		14	14		3	4		12	12	
UTTAR PRADESH															
Area	5389	5932	0.32NS	7772	9230	0.65**	1174	901	-2.2NS	686	314	-4.4**	686	332	-3.1**
Rank	1	1		1	1		1	2		1	1		7	6	
Production	5898	11615	4.73**	12749	23169	3.25**	1004	924	0.70Ns	744	635	-1.0*	405	237	0.3NS

Rank	2	2		1	1		1	7		1	1		7	6	
Yield	1094	1958	4.35**	1640	2510	2.55**	855	1025	2.56NS	1084	2022	3.05*	590	713	2.7NS
Rank	11	7		5	3		13	11		5	3		8	7	
WEST BENGAL															
Area	5210	5904	0.94**	214	367	1.24NS	60	38	-2.1*	35	6	-4.4**	0.2	0.9	0.75*
Rank	3	2		11	10		20	14		7	7		22	22	
Production	5833	13317	4.73**	389	778	1.80*	71	121	1.90*	31	6	-4.2**	0.1	4	0.35NS
Rank	3	1		13	8		20	11		7	7		20	18	
Yield	1119	2255	3.72*	1817	2119	0.50NS	1183	3184	3.93**	881	1000	0.30*	500	444	-0.4NS
Rank	8	6		4	5		9	3		6	7		10	10	
ALL INDIA															
Area	40156	44802	0.38**	22220	27523	0.72**	5900	6083	0.38**	1800	780	-4.7**	15800	9980	-2.1**
Production	53631	86076	2.82**	37353	71287	3.50**	6900	10678	2.59**	2100	1468	-2.1**	10431	8713	-0.7NS
Yield	1335	1921	2.42**	1681	2590	2.55**	1169	1755	2.19**	1162	1882	2.52**	660	873	1.33*

Note : *, ** represents significant at 5% and 1% level of significance
Ranks are assigned on all India basis.

Table 1.1 Area and production levels of food grain crops and their growth from 1990-91 to 2009-10 in selected states of India
Area in 000 hectare Production in 000 metric tones Yield in Kg./Hect

	Bajra			**Total cereals**			**Tur**			**Gram**			**Total pulses**			**Total**		**Food**
States	199	200	C.G.R	1990-	2009-	C.G.R	199	200	C.G.	199	200	C.GR	199	2009	C.G.RR.	1990	200	C.G.R
ANDHRA PRADESH																		
Area	544	122	-8.2**	7310	5620	-1.1*	248	370	2.43*	248	137	-	150	1568	1.39NS	8756	718	-0.4^{NS}
Rank	7	9		6	9		5	5		6	7		6	6		6	7	
Producti	444	114	-6.3**	9972	1363	1.80**	60	165	6.49*	24	84	10.77	560	763	2.64**	1141	143	1.22*
Rank	6	10		4	5		7	6		17	9		7	5		4	4	
Yield	816	934	1.78*	1364	2426	2.90**	241	445	3.98*	96	613	10.35	373	487	1.20NS	1303	200	1.80*
Rank	3	6		4	3		12	12		11	9		11	10		9	7	
BIHAR																		
Area	12.7	6.0	-1.9*	8657	8046	-0.4^{NS}	94	66	-^{NS}	173	126	-	136	912	-1.9**	1002	895	1.40N
Rank	17	18		5	5		8	9		8	8		8	9		5	5	
Producti	6.6	3.5	-1.8*	7424	1221	1.99*	91	99	0.35	124	97	-	815	698	1.4**	8239	129	2.64**
Rank	18	18		5	6		6	8		7	8		6	8		6	6	
Yield	519	583	0.15N	857	1518	2.05*	971	149	1.05	716	769	-	597	764	0.4NS	821	144	1.03*
Rank	8	10		13	8		4	1		3	6		6	4		10	8	
HARYANA																		
Area	852	606	-2.5**	3178	4063	2.46*	7	41	3.32	104	357	-	810	427	-1.5**	3982	449	1.70*
Rank	5	5		13	11		12	11		4	5		9	11		12	11	
Producti	496	611	1.33N	5525	1177	4.61**	9	47	3.25	309	295	-	515	353	-0.6NS	6040	121	4.0**
Rank	5	5		8	7		13	10		4	5		8	10		9	9	
Yield	582	100	3.70N	1738	2897	2.05*	136	113	-	295	826	4.20*	635	827	0.9*	1516	270	2.15**
Rank	6	4		2	2		1	4		10	3		4	2		3	2	
KARNATAKA																		
Area	635	417	-2.2**	5136	5570	0.85N	374	460	0.74	144	355	2.25*	149	1812	0.89*	6622	738	0.90*
Rank	6	6		9	8		4	2		9	6		7	5		8	6	
Producti	323	293	0.65N	6808	9255	2.61**	183	222	0.41	58	198	3.15*	500	722	1.11NS	5880	997	2.24**
Rank	8	8		9	10		5	5		13	7		9	6		11	10	
Yield	508	702	1.55*	1325	1662	1.70**	489	482	0.30	401	557	0.99*	334	398	0.25NS	887	135	1.30*

Rank	9	9		5	10		10	11		8	10		10	13		12	13	
MADHYA PRADESH																		
Area	199	141	-1.1*	1322	1274	0.57N	534	403	-	202	266	1.61*	457	5040	1.92*	1779	177	0.45N
Rank	9	8		2	2		2	4		1	2		1	1		2	2	
Producti	121	166	0.70N	1082	1622	2.30**	482	347	-	136	246	3.94*	201	3573	3.99**	1283	197	2.50**
Rank	13	9		3	3		2	3		1	1		2	1		3	3	
Yield	607	117	1.90**	818	1273	1.70*	902	861	0.49	671	924	2.27*	439	709	1.99**	721	111	1.90**
Rank	5	2		14	14		5	6		5	1		7	5		14	14	
MAHARASHTRA																		
Area	174	175	0.43N	1124	9594	0.75N	706	100	3.64*	461	904	3.60*	283	3500	2.22**	1405	130	0.75N
Rank	2	2		3	3		1	1		5	3		3	3		3	4	
Producti	779	149	3.72**	9671	1049	1.29N	427	809	4.04*	177	561	7.16*	900	2255	5.08**	1057	127	1.67**
Rank	3	2		6	8		3	1		5	4		5	4		5	8	
Yield	446	848	3.15**	860	1094	0.60N	604	804	0.37	383	620	3.40*	317	644	2.80**	752	974	0.80N
Rank	8	7		11	16		8	9		9	8		12	7		15	15	
PUNJAB																		
Area	71	4	-4.9**	4505	6046	1.54**	18	9	-2.7*	243	13.2	-	300	78	-5.0*	4843	612	1.96*
Rank	15	19		10	7		11	16		7	12		13	13		10	9	
Producti	89	4	-5.0**	1314	2285	3.53**	18	5	-	115	10.4	-	185	51	-4.0**	1332	229	3.05**
Rank	14	17		2	2		10	14		6	12		12	13		2	2	
Yield	125	100	0.3NS	2916	3780	1.99*	100	621	0.3N	473	787	0.95N	616	653	1.05NS	2751	374	1.04N
Rank	1	5		1	1		3	11		7	5		5	6		1	1	
RAJASTHAN																		
Area	494	417	-	9197	8818	1.33N	35	25	-	193	281	1.16N	306	4644	0.87*	1234	134	1.16N
Rank	1	1		4	4		9	12		2	1		2	2		4	3	
Producti	804	179	5.5*	6163	1049	2.98**	12	33	1.90*	125	207	1.74N	100	2444	2.54**	7163	129	3.31**
Rank	2	1		11	9		12	12		2	2		3	2		7	7	
Yield	162	430	4.66**	670	1190	1.55**	349	132	3.55*	649	736	0.55*	326	526	1.70*	580	961	1.90*
Rank	10	12		17	15		11	2		6	7		9	9		16	16	
UTTAR PRADESH																		
Area	975	779	-1.1**	1761	1779	0.8NS	515	425	-	157	881	-	279	2718	0.16NS	2047	205	0.97N
Rank	4	4		1	1		3	3		3	4		4	4		1	1	
Producti	679	948	1.63**	2188	3787	3.21**	630	498	-	106	725	-	240	2269	0.32NS	2428	401	2.95**
Rank	4	3		1	1		1	2		3	3		1	3		1	1	
Yield	696	118	2.70*	1242	2128	2.29**	122	117	-	675	822	0.25N	860	835	0.25NS	1186	195	1.85*
Rank	4	1		6	5		2	3		4	4		1	1		8	4	
WEST BENGAL																		
Area	1.1	0.2	-3.2*	5575	6335	1.90*	22	3	-	90	23	-	500	203	-	6099	6536	1.12*
Rank	20	20		7	6		10	17		11	11		12	12		9	8	
Producti	0.6	0.1	-4.5**	6350	1424	4.46**	17	2	-	70	19	-	200	126	-	6550	14367	4.09**
Rank	19	20		7	4		11	16		9	10		11	12		8	5	
Yield	545	500	-	1139	2248	2.48**	772	661	-	777	826	1.96*	400	621	1.75	1073	2198	2.90*
Rank	7	11		7	4		7	10		1	2		8	8		4	3	
ALL INDIA																		
Area	116	929	-0.8*	1042	1015	0.50N	280	343	1.15*	650	846	-	238	238	-	1296	125167	-0.2
Producti	534	695	1.66N	1180	1882	2.68**	190	270	0.90	430	680	1.15*	115	148	0.85	1336	203606	2.60**
Yield	458	748	2.50	1133	1854	2.05*	678	787	-	661	802	1.20*	483	622	0.99	1030	1626	2.79**

Note : *, ** represents significant at 5% and 1% level of significance Ranks are assigned on all India basis.

VII. Conclusion

It was found that Uttar Pradesh remained the leading grower of paddy throughout the study period. Andhra Pradesh which was the leading producer of rice in 1990-91, while Andhra Pradesh lagged to the third position. The highest growth rate in production of rice was recorded in Punjab where the production grew at the rate of 4.93 percent per annums while Maharashtra was the one study state where growth rate in production was the least. All India yield indicated that Madhya Pradesh had logged much behind all other states as it yield which was 41 percent lower than all India average.

Uttar Pradesh remained the leading grower and producer of wheat through out the study period followed by Punjab and Madhya Pradesh. Productivity was Punjab ranked first in both periods followed by Haryana. The highest growth rate in production of wheat was recorded in Madhya Pradesh. The wheat production in India grew at the rate of 3.50 percent per annum.

Uttar Pradesh remained the leading grower of maize crop through out the study period followed by Rajasthan. On production front Karnataka became the leading producer of maize crop in 2009-10 by improving its rank from 10^{th} in 1990-91 to first rank in 2009-10. Punjab was the one study state where the highest deceleration in production of maize was recorded where the production declined at the rate of 3.44 percent per annum. Rajasthan had lagged much behind all other states as its yield which was 70 percent all are India average in 1990-91 further remained to 61 percent lower than all India average by 2009-10. In barley crop, Uttar Pradesh again remained the leading grower of Barley crop through out the study period followed by Rajasthan and Madhya Pradesh in order while Maharashtra remained the lowest grower of Barley. This crop recorded the negative growth in all the study states through out the study period. The production of Barley crop in India declined at the rate of 2.15 percent per annum due to the major negative trend in area (4.70) per annum. Maharashtra remained the leading grower and producer of Jowar crop through out the study period followed by Karnataka. On yield front Bihar improved its rank from 9^{th} place to 4^{th} places. The least productivity was observed in Haryana 193 Kg. per hectare. Jowar crop recorded the negative growth in all the study states through out the study period. In all the study states decline in production is due to the high decline in area.

In India, Rajasthan remained the leading grower and production of Bajra crop sharing 44.85 percent of crop area in India. On productivity front the highest yield was recorded in Uttar Pradesh followed by Madhya Pradesh in 2009-10. The highest deceleration in production of Bajra was recorded in Andhra Pradesh where the production declined at the rate of 6.39 percent per annum followed by Punjab and West Bengal.

In India, Uttar Pradesh remained the leading grower of cereals followed by Madhya Pradesh, Maharashtra, Rajasthan and Bihar in order. Highest growth in cereals production was recoded in Haryana where it grew at the rate of 4.61 percent per annum. The highest growth in productivity was observed in West Bengal. On productivity front Punjab attained first rank followed by Haryana.

In Tur, Maharashtra remained the leading grower and producer of this pulse through out the study period. The highest improvement in productivity was recorded in Rajasthan the rank of the state improved from 11^{th} position to 2^{nd} position while the rank of Punjab declined from 3^{rd} place to 11^{th} place. The highest growth in production of Tur crop was recorded in Andhra Pradesh where it grew at the rate of 6.49 percent per annum. Rajasthan is the leading grower of gram crop, while Madhya Pradesh remained the leading producer of this crop. In Andhra Pradesh the production of gram crop grew at the rate of 10.77 percent per annum, due to the high contribution of growth in productivity. In India, Madhya Pradesh and Rajasthan found the larges producer and grower of pulses in order through out the study period. Punjab found the least grower of pulses among study states followed by West Bengal. The highest productivity of pulses crop was recoded in Uttar Pradesh followed by Haryana. The highest growth in the production of pulses crop was recorded in Maharashtra where the production grew at the rate of 5.08 percent per annum. In India, Uttar Pradesh, Madhya Pradesh, Punjab, Rajasthan, Maharashtra, Bihar and West Bengal have attained the dominant position in production of food grains. These states together contribute more than 60 percent to total foodgrain production of India. Highest productivity of grain was found in Punjab, while the least was found in Rajsathan. The highest growth in the production of foodgrain was recorded in West Bengal. Where production grew at the rate of 4.09 percent per annum. Growth in production only because of growth in area was observed in Punjab among all the study states. It shows that yield level of this state may have touched the stagnant level. The least growth in the production was found in Andhra Pradesh.

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