Rice and Jute yield forecast over Bihar region

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Abstract

Crop Yield forecasting (approximately one month in advance) play an important role in decision making and planning of food need in future. In this paper we have compared results of the statistical model of crop yield forecast for rice and jute crops for the year 2012-to 2014 of all districts of Bihar (for rice) and 6 districts of Bihar (for jute). The statistical model is based on the correlation and regression approach in which weather parameters are incorporated along with technological trend at various stages of the growth of rice and jute crop. The model prediction as technological trend alone and along with weather shows considerable difference in yield productivity of rice and jute. It is seen from the study that for rice the yield departure from actual ranges -10 % to 12 % and -20 % to 35 % during the years 2012 to 2014. It has been brought out that the yield prediction model used operationally in India Meteorological Department (IMD) under the project forecasting of agriculture output using space, agro meteorology and land based observations (FASAL) shows approximately 60 % improvement after incorporated the weather data in the yield analysis. Almost similar performance has been observed for jute yield during the years 2012 to 2014. The model predicted yield results for rice and jute for the year's 2012 to 2014 shows reasonably good agreement with the actual yield.

Key words: Statistical model, crop yield, jute and rice.

1. INTRODUCTION

Early and in season crop production forecasting play an eminent role in coordination and planning of food sectors in India. The crop yield forecast based on the empirical statistical regression approach by India Meteorological Department (IMD) is done about a month before the harvesting period. The importance of weather data on crop yield is well known and affects the production.

India's 2.4 % geographical area and 4 % water resources shares 17 % human population and 14 % livestock (State of Indian Agriculture, 2012-2013). The evolution of rice as a food crop depends primarily on the rainfall and in low rainfall areas the variability is high regardless the latitude. Spatial and temporal vulnerabilities in rice production at regional level depend on the monsoon onset, advance and withdrawal performance, especially rain fed regions. Besides all the vagaries of monsoon rainfall and variability India is the second is in second rank for rice production (DAC, Annual report, 2005-2006)The growing season of rice in dry season /wet season according to Rice Almanac (Maclean, 2003) and Siddiq (2006) for Bihar region is June –July to October –November and Mid June to October respectively. There are certain meteorological parameters like temperature; rainfall and sun shine duration which is generally responsible for the optimum growth of the rice crop. The yield predictions of the crop much before the harvesting of crop has been made for most of the crops (Rice and Jute for this work) for proper coordination and planning the activities in ministry of agriculture. India Meteorological Department (IMD) is using empirical – statistical model using step-wise correlation and multiple regression approach for crop yield forecasting under the ministry of agriculture project forecasting of agriculture output using space, agro meteorology and land based observations (FASAL).

Nearly 76 % population of the Bihar is dependent on agriculture. 53.06 lakh hectares is the net cultivated area out of 93.60 lakh hectare area. Bihar region is bounded by the humid region (West Bengal) in east and humid region Uttar Pradesh in west. The crops like rice required adequate amount of rainfall and good ground water availability in case of deficient rainfall. There are 111 rice growing countries in the world and bulk of the rice production is cantered in wet tropical climate.

Population growth and persistent poverty gives alarming signal of the growing food needs. The food productivity is also affected naturally and human induced activities. In recent past human induced activities has been increased and a report of Global Assessment of Land Degradation (GLASOD) show that in India alone land degradation vary from 53 million ha right up to 239 million ha based on expert judgments of public authorities. The map (figure 1) adapted from the study of Oldeman et al (1991) below shows different soil degradation types around the world.

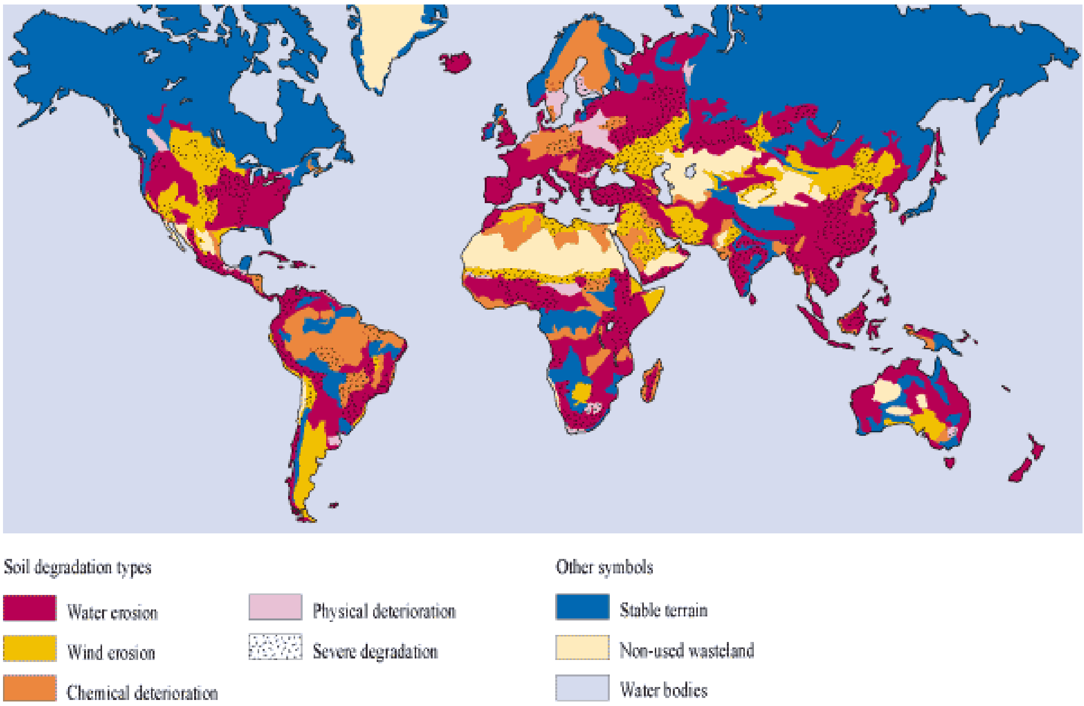

Figure 1: Human induced soil degradation (Courtesy by Oldeman et al, 1991).

The uses of Jute (Corchorus capsularis L & C. olitorius L) fibbers are very much popular from ancient times (eighteenth century). Even today jute has become indispensable to almost every nation. The state of Bihar has been growing Jute in scattered pockets. In the present work 6 districts of Bihar has been chosen for predicting the yield forecast using statistical approach followed under FASAL project. Moderate rainfall, warm and humid atmosphere supports the Jute growth. During the south west (SW) monsoon season the precipitation distributed over 80 to 90 days. Strong sunshine and moderately strong wind alternating with rains are conductive to good growth except frequent or heavy rains. A crop shown during the monsoon or in a situation where weeding or thinning is required during that phase seldom gives either a uniform crop or high yield. In the current scenario the jute production is labour intensive and costly, therefore rain fed uplands of Bihar using jute based cropping system (Mitra et al, 2006). Normal jute crop cycle in Bihar ranges from March to July each year. Previous year studies conducted by India Meteorological Department (IMD) and Indian Agricultural Statistics Research Institute (IASRI) have shown ample scope for using these models during early stages of crop growth (Sarwade 1985, Agrawal et al., 1983, 1986).

2. DATA AND METHODOLOGY

The weather data used in the statistical model of yield prediction of rice and jute from the years 1990-2014 is taken from meteorological centre Patna. Weather variables are used as independent variables which are related to crop responses such as yield. To account for the technological changes function of time is used as independent variable. The forecast model used for the study is given below:

The general equation of the model is (Vashisth et al, 2014, Giri et al, 2015)

$$\Gamma = \alpha_0 + \sum_{i=1}^{p} \alpha_{ij}\beta_{ij} + \sum_{i \neq i'=1}^{p} \sum_{j=0}^{l} \alpha_{ii'j}\beta_{ii'j} + \gamma T + \delta$$

Where,

$$\beta_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw}$$

and

$$\beta_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j} X_{i'w}$$

r_{iw} is the correlation coefficient of Yield (Γ)

Γ is the estimated yield (kg/ha)

α_0 =regression constant

r_{iw} is the correlation coefficient of yield with i-th weather variable in w-th period.

$r_{ii'w}$ is the correlation coefficient (adjusted for trend effect) of yield with product of i-th and -th weather variables in w-th period.

m is period of forecast

P is the number of weather variables used

e is random error distributed as N(0, σ^2)

3. RESULTS AND DISCUSSION

In this study, rice and jute crop yield forecast has been analysed over Bihar region. Rice crop has grown all districts of Bihar during July to November and mainly depends on monsoon rain. In rain fed areas other crop varieties were used in different showing dates. The jute crop is grown in scattered areas, mainly north –east (NE) region of Bihar during February end to July first week time. Both the crops were matured within a year time. Statistical model generated yield forecast for both the crops has been generated about a month before the harvesting time

The weather variables used for analysis are given in table (1) of all the three agro climatic zones (figure 1). The regression equations obtained from the statistical analysis for all 38 districts are given in table 2 and table 3 for rice and jute crop respectively. Pre-harvesting predicted yield forecasting has been compared with the actual yield data of rice and jute with technological trend and along with weather & technological trend data. The obtained results were found satisfactory and closer to the actual yield data. The results were deviated more if we consider the technological trend alone. After inclusion of weather inputs along with the technological trend data the model shows approximately 60 % improvement for both the crops. Table 2 and 3 shows that the significant contributory variables are rainfall and temperature and in some cases relative humidity also contributed. Figures (2 to 7) indicates yield departures of rice and jute for the years 2012 to 2014. The model has run till 2014 weather data. In the figures, 2 to 7, W indicates the output based on weather and NW indicated without weather results. These results are very useful in future planning in the light of sustainability or management of food security for the country.

4. CONCLUSIONS

The crop yield results of rice and jute obtained after the statistical –regression model run (data used till 2014) shows that:

(1) Model predicted yield with weather and technological trend analysis agrees reasonably well with actual yield data for both rice and jute.
(2) Technological trend results have been improved nearly 60 % with weather data.
(3) Pre-harvesting yield prediction can be taken as a pre-cursor for future planning of food grains and important input for ministry of agriculture.

ACKNOWLEDGEMENT

Authors are grateful to Director General of Meteorology for data and financial support under FASAL project. The contribution of meteorological centre Patna staff duly acknowledged.

Figure 1: Agro climatic zones of Bihar (✧ represents Jute growing districts)

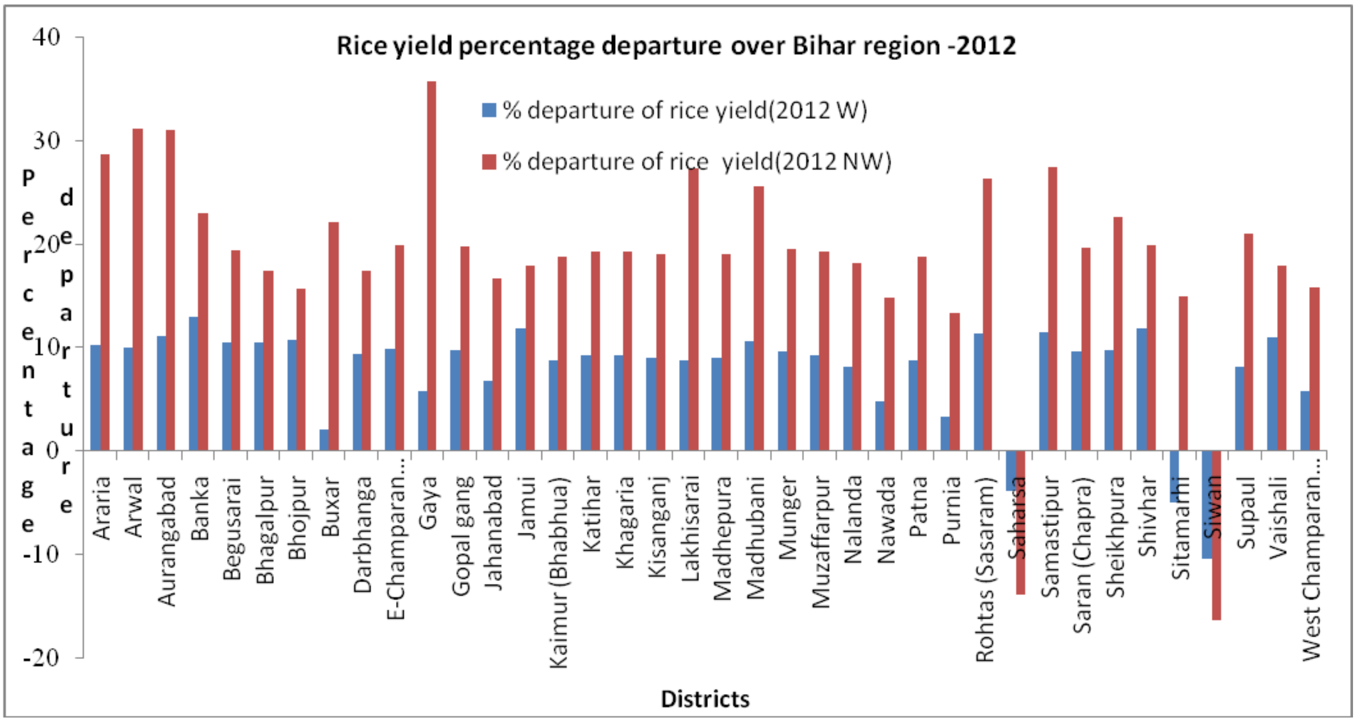

Figure 2: Rice yield departure (actual –model predicted) for the year -2012

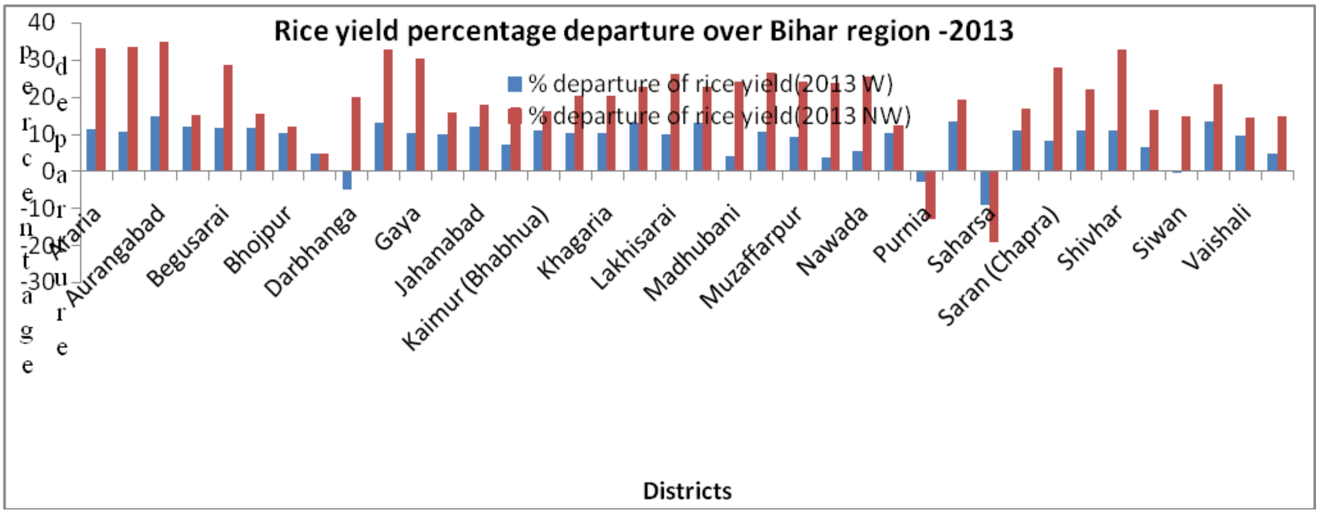

Figure 3: Rice yield departure (actual –model predicted) for the year -2013

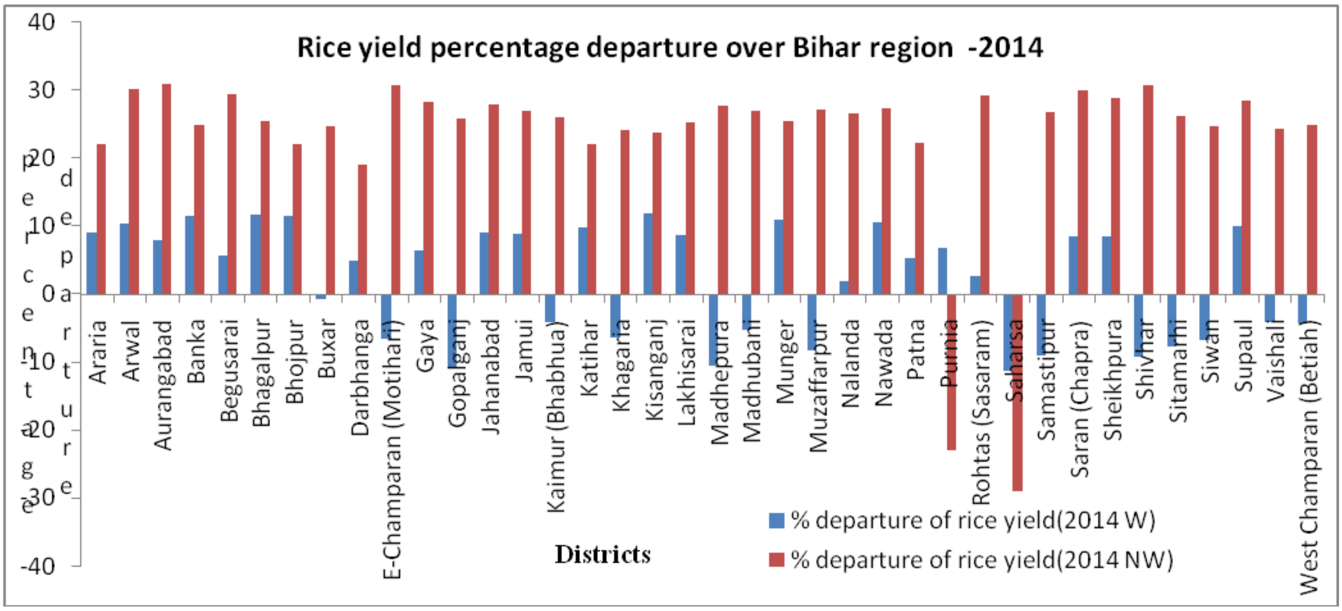

Figure 4: Rice yield departure (actual –model predicted) for the year -2014

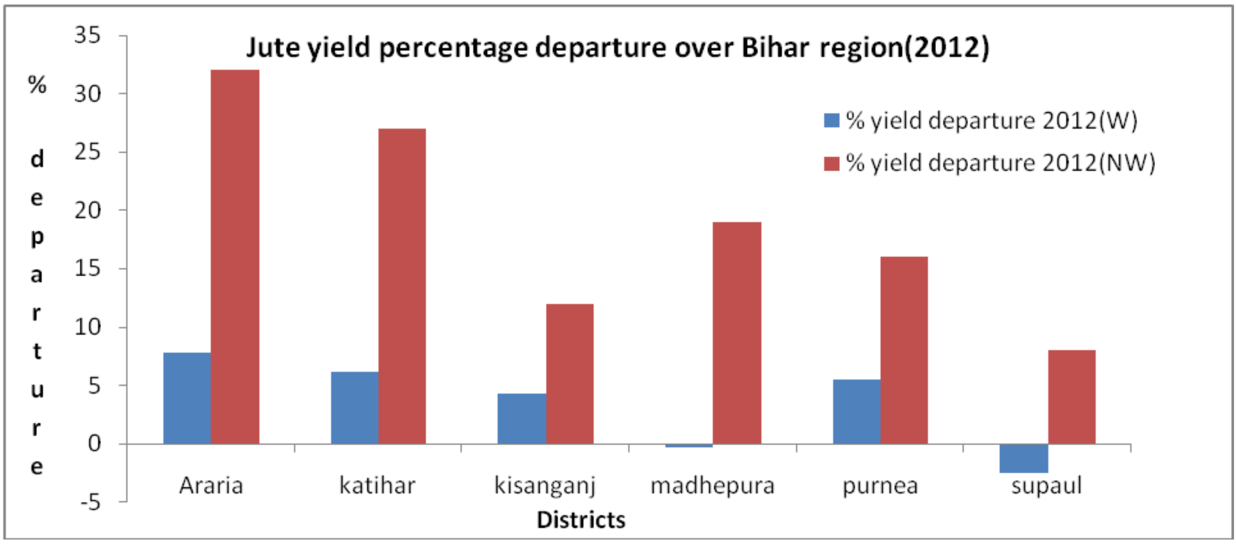

Figure 5: Jute yield percentage departure (actual –model predicted) for the year -2012

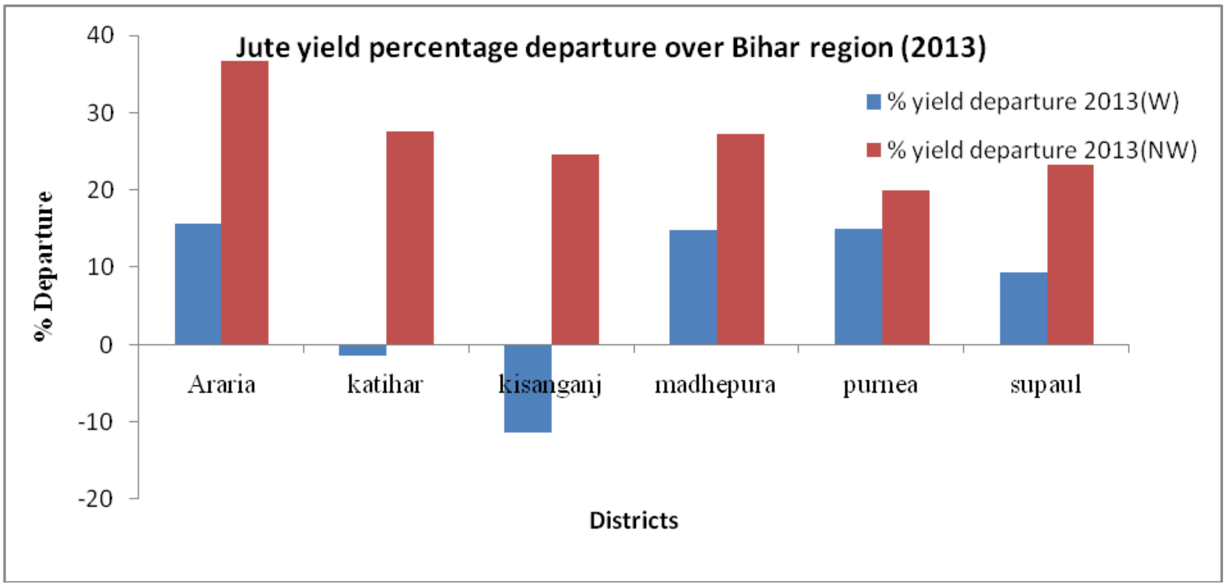

Figure 6: Jute yield percentage departure (actual –model predicted) for the year -2013

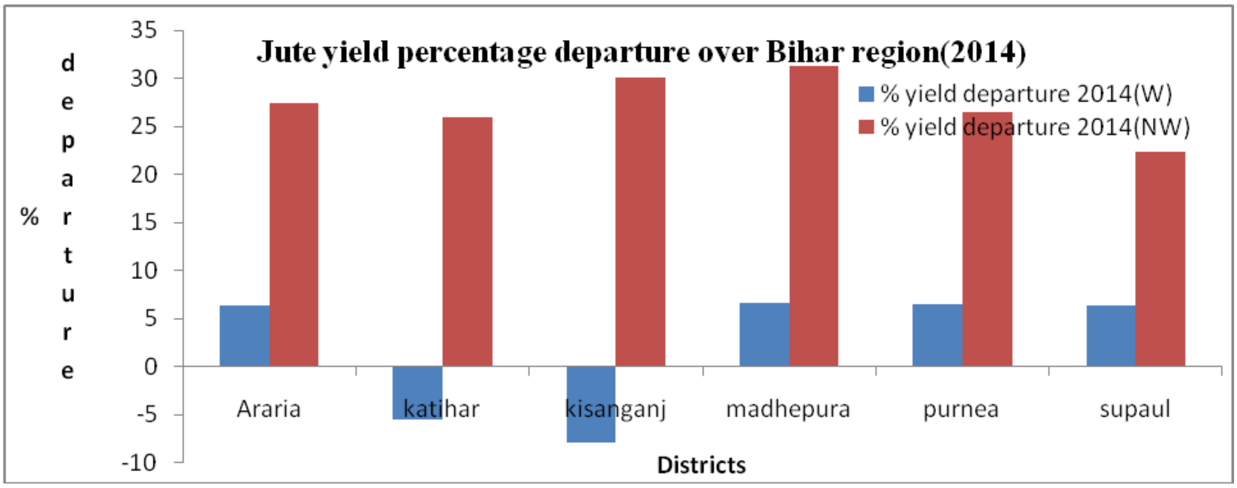

Figure 7: Jute yield percentage departure (actual –model predicted) for the year -2014

Table 1: Variables used in development of statistical models

Symbols	Description	Symbols	Description
Z11	Weighted coefficients for Tmax	Z140	Un-weighted coefficients for Tmax*RH-I
Z10	Un-weighted coefficients for Tmax	Z151	Weighted coefficients for Tmax*RH-II
Z21	Weighted coefficients for Tmin	Z150	Un-weighted coefficients for Tmax*RH-II
Z20	Un-weighted coefficients for Tmin	Z231	Weighted coefficients for Tmin*Rain

Z31	Weighted coefficients for Rain	Z230	Un-weighted coefficients for Tmin*Rain
Z30	Un-weighted coefficients for Rain	Z241	Weighted coefficients for Tmin*RH-I
Z41	Weighted coefficients for RH-I	Z240	Un-weighted coefficients for Tmin*RH-I
Z40	Un-weighted coefficients for RH-I	Z251	Weighted coefficients for Tmin*RH-II
Z51	Weighted coefficients for RH-II	Z250	Un-weighted coefficients for Tmin*RH-II
Z50	Un-weighted coefficients for RH-II	Z341	Weighted coefficients for Rain*RH-I
Z121	Weighted coefficients for Tmax*Tmin	Z340	Un-weighted coefficients for Rain*RH-I
Z120	Un-weighted coefficients for Tmax*Tmin	Z351	Weighted coefficients for Rain*RH-II
Z131	Weighted coefficients for Tmax*Rain	Z350	Un-weighted coefficients for Rain*RH-II
Z130	Un-weighted coefficients for Tmax*Rain	Z451	Weighted coefficients for RH-I*RH-II
Z141	Weighted coefficients for Tmax*RH-I	Z450	Un-weighted coefficients for RH-I*RH-II

Table 2: District –wise Rice crop yield equations over Bihar region

S.No.	District	Regression equations	Weather element	% deviation with actual yield		
				2012	2013	2014
1	Araria	1524.6+z131*252.21+time*54.6	Tmax*Rain	10.21	11.14	8.97
2	Arwal	115.85+z341*0.49	Rain*RH-I	9.94	10.61	10.30
3	Aurangabad	207.7+z340*3.22+z241*1.92	Tmin*RH-I,Rh-I*rain	11.13	14.86	7.96
4	Banka	1218.6+time*75.3+z21*105.28+z341*28.68	Tmin,RH-I,Rh-I*rain	13.01	11.97	11.4
5	Begusarai	-1665.46+time*64.1+z41*20.2+z231*10.05	RH-I,Tmin*Rain	10.44	11.50	5.64
6	Bhagalpur	6158.7+66.5*z11+16.7*z41	Tmax,RH-I	10.48	11.51	11.68
7	bhojpur	6897.54+z251*1.0+z351*0.1+z451*0.23	Rain*Rh-II,Rh-I*Rh-II	10.76	10.08	11.55
8	Buxer	2675.2+time*65.16+z120*1.5+z451*2.1	Tmax*tmin,rh-I*rh-II	2.13	4.64	-0.66
9	Darbhanga	1726.+82.79*time+58.2*z21+1.08*z341	Tmin,rain*rh-I	9.43	-5.04	4.92
10	East_champaran	2456.5-z131*1.58+z41*15.7	rain,tmax*rh-I	9.86	12.84	-6.66
11	Gaya	983.1+time*77+z241*1.08+z341*1.3	Tmin*RH-I, rain*RH-I	5.81	10.22	6.35
12	Gopalganj	-595.63+time*64.37+z41*18.78+z231*7.17	Tmin*RH-I, Tmin*rain	9.78	9.82	-10.66
13	Jahanabad	1595.39+z121*7.4	Tmax*Tmin	6.75	11.87	9.14
14	Jamui	432.98+time*81.84+z251*2.55+z341*0.07	Tmin*RH-II,rain*RH-I	11.87	7.06	8.88
15	Kaimur	1148.3-z30*8.13+z41*46.42	Tmax,rh-I,rain	8.82	11.00	-4.16
16	Katihar	-206.52+time*73.11+z231*1.93		9.29	10.15	9.89

17	Khagaria	-665.4+time*64.10+z41*20.20+z231*10.05	Rh-II,tmin*rain	9.29	10.15	-6.46
18	Kisanganj	807.031+time*52.28+z31*93.37	Tmin,rain	9.07	12.83	11.80
19	lakhisarai	-1492.07+z251*1.00+time*49.71	Tmin*RH-II,time	8.74	9.97	8.58
20	madhepura	2840.3+time*46.8+z11*137.15+z351*.069	Tmax,rh-II,RH-II*rain	9.07	12.83	-10.61
21	Madhubani	-78.19+time*51.31+z41*18.99+z251*.06	Rh-I,tmin*rh-II	10.58	3.91	-5.30
22	munger	-536.35+time*51.01+z131*.41+z141*.63	Tmax*rain,tmax*rh-I	9.57	10.55	11.03
23	muzzafarpur	3986.27+time*56.16+z241*2.44-z251*1.9	Tmin*rh-I,tmin*rh-II	9.25	9.21	-8.35
24	nalanda	6185.2-z40*2.61+z151*.43+z241*1.51	Rh-I,tmin*rh-I	8.14	3.55	1.92
25	nawada	983.12+time*77.46+z241*1.08+z341*1.37	Tmin*rh-I,rain*rh-I	4.78	5.29	10.56
26	patna	-141.55+z241*1.85+time*51.23	Tmin*rh-I	8.76	10.19	5.28
27	purnea	1494.63+time*52.45+z241*.924	Tmin*rh-I	3.36	-3.08	6.81
28	rohtas	1920.655+z251*1.72+time*93.72+z341*2.0	rain*rh-I,tmin*rh-II	11.37	13.26	2.63
29	saharsa	3675.266+z141*.482-z240*0.11+z451*.13	Tmax*rh-I,tmin*rh-I	-3.90	-9.09	-11.30
30	samastipur	1235.92+time*87+z251*1.35	Tmin*rh-II	11.46	10.79	-9.09
31	saran	-595.63+time*64.37+z41*18.78+z231*7.17	Rh-I,tmin*rain	9.66	8.01	8.57
32	sheikhpura	4558.59+31.64*z11+1.07*z241	Tmax,tmin*rh-I	9.70	10.93	8.40
33	sivhar	996.85+time*37.71	time	11.86	10.84	-9.23
34	Sitamadhi	3070.86+time*41.26+z241*1.922+z250*0.189	Tmin;RH-I	-4.96	6.29	-7.65
35	siwan	1052.29+time*75.4+z231*9.83	Tmin*rain	-10.43	-0.69	-6.84
36	Supaul	1282.38+time*55.88+z31*76.0+z241*0.66	Rh-I,tmin*rh-I	8.08	13.42	9.96
37	vaisali	980.50+time*86.05+z51*12.65+z231*9.30	Rh-II,tmin*rain	10.97	9.40	-4.13

38	westchamparan	5219.225-11.3*z131	Tmax*Rain	5.85	4.83	-4.25

Table 3: District –wise Jute crop yield equations over Bihar region

S.No	Districts	Equations	Weather parameter	Percentage error of yield 2012	Percentage error of yield 2013	Percentage error of yield 2014
1	Araria	1223.7-z11*32.21-z341*0.034-z350*0.007	Tmax,Rain*Rh-I	9.40	7.84	8.92
2	Katihar	1154.54+54.428*time+z131*1.45-1.6*z231+z340*0.0098	Tmax*Rain, Tmin*rain,rain*rh-I	5.67	6.14	7.61
3	Kisanganj	1004.73+time*35.37-z1310.186	Tmax*rain	8.56	4.26	4.60
4	Madhepura	-3926.18-z11*46.418-0.178*z131+time*57.51	Tmax,tmax*rain	9.33	-0.31	6.91
5	Purnea	3308.75+z20*6.78-187.44*z21+time*17.33	Tmin, Rain	9.16	5.48	8.80
6	Supaul	2349.69+time*98.82+z31*4.1+z121*0.82	Rain,Tmax*Tmin	-6.82	-2.51	9.31

REFERENCES

[1] Agrawal, R., Jain, R.C. and Jha, M.P. (1983). *Joint effects of weather variables on rice yields.*, Mausam, vol. 34, pp 189-194.

[2] Agrawal, R., Jain, R.C. and Jha, M.P. (1986). Models for studying rice crop- weather relationship. Mausam, vol. 37, pp 67-70

[3] Annual Report 2005-2006. *Department of Agriculture and Cooperation, Ministry of Agriculture,* Government of India, 130 p

[4] Giri, R.K., Pradhan, Devendra, Sen, A.K and Parbat, S.K., (2015). *Role of weather parameters in crop yield forecasting of wheat over Bihar region*, International journal of latest research in engineering and Science, 1,1,11-20.

[5] Maclean, J. L., Dawe, D. C., Hardy, B., and Hettel, G. P. (2003). *Rice almanac*. Third edition. Los Ban˜os, Philippines.

[6] Mitra, Sabyasachi, Maiti, S. N. and Sarkar, Sitanshu. 2006. *Recommendations for jute and allied fibre crops : A*n endeavour of All India Network Project. p.28, CRIJAF, Barrackpore, Kolkata

[7] Oldeman, L.R. Hakkeling, R.T.A., Sombroek, W.G. (1991). *World Map of the Status of Human-Induced Soil Degradation:* An Explanatory Note, UNEP and ISRIC, Wageningen.

[8] Siddiq, E. A. (2006). *Field crops: Rice. In Handbook of Agriculture, pp. 817–844.* Indian Council of Agricultural Research, New Delhi

[9] Sarwade, G.S. (1985). *Crop yield forecast of paddy and wheat.* Presented at International WMO/FAO/IMD Workshop on Application of operational techniques in Agrometeorology, at Pune.

[10] State of Indian Agriculture, 2012-2013: *A report Ministry of Agriculture*, Department of Agriculture and Cooperation, Directorate of Economics and Statistics, New Delhi

[11] Vashisth, Ananta., Singh, R., and Choudary ,Manu., (2014). '*Crop Yield Forecast at Different Stage of Wheat Crop Using Statistical Model under Semi Arid Region,* Journal of Agroecology and Natural Resource Management, 1 (1), 1-3

[12] WMO (1966). *WMO Technical Note No.79*, WMO No. 195-TP100, WMO, Geneva, pp.79.

Biography

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