Estimating future yield of wet season rice in Chhattisgarh using crop simulation model

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ABSTRACT

Crop forecasting through anticipation of future weather pattern and timely decision of proper agricultural management practices to avoid sudden crop failure is one of the advanced ways of sustainable agriculture. Crop growth simulation model can be successfully used to asses the yield under changing climatic condition which may be useful for developing adaptation and mitigation measures. Considering the fact, an attempt has been made to predict the future yield of rice in plane region of Chhattisgarh using Decision Support System for Agrotechnology Transfer (DSSAT v 4.5). Management combinations simulated were three sowing dates 11th June, 21th June and 29th June in 2011 and 10th June, 15th June and 22nd June in 2012 for wet season rice cv. Karmamasuri under rainfed and irrigation condition. Thirty three year (1981-2012) weather data (Max T, Min T, Rainfall and Radiation) was collected from IGKV, Raipur. First, the DSSAT v4.5 model was calibrated and validated for locally popular medium duration variety Karmamasuri for wet season (2011-2012). The result showed that the early and late sowing dates gave lower yield as compared to optimum sowing dates. The weighted yield was observed more than actual yield in central Chhattisgarh.

Key words: *rice, climate change, estimated, yield, simulation model*

Information needs for agricultural decision making at all levels are increasing rapidly due to increased demands for agricultural products and increased pressures on land, water, and other natural resources. With the ongoing consciousness and threat due to climate change it is important to assess the associated impacts on agricultural production. The annual global temperature increase is 0.74°C in past 100 years (INCCA, REPORT-2 2011) and projected increase of temperature may be 2.4ºC to 5.8ºC in 2100 (IPCC 2007). Recent INCCA report and other worldwide studies show a probability of 10-30% loss in crop production in India with increase in temperature around 2050. The long term future climatic projections have been generated by various global circulation models (GCM) and regional circulation model (RCM). Simulation model becomes a very essential tool to predict the future yield of a crop and the possible adaptation measure against that (Aggarwal and Mall, 2002). Rice is the most important staple food crop in India, grown under varying ecological conditions. Due to increased climatic variability and uncertainty associated with climate change, the production of rice may be hampered. Hence an investigation was carried out for estimation of future yield of wet season rice in Chhattisgarh using DSSAT v4.5 model.

MATERIALS AND METHODS

The field experiment was carried out at the Labhandi farm of Indira Gandhi Krishi Viswavidyalaya, Raipur under Inseptisol Zone of Chhattisgarh. The climate of the study area falls under sub-tropical (dry moist to sub humid) climate. The region receives an average of 1200 mm annual rainfall, out of which about 87 per cent is received during the rainy season (June to September) and the rest during the other season (October to February). January is the coolest and May is the hottest month. The maximum and minimum temperature ranges from 26.7^{0}C to 42.5^{0}C.

Atmospheric humidity varies between 70 and 90 per cent from mid June to March and wind velocity is high from May to August with its peak in June-July months. Soil surface temperature of this region crosses 60^{0}C, air temperature to 48^{0}C and humidity drops down to 3 to 4 per cent during summer season.

Field experiments were conducted during wet season 2011 and 2012 at Raipur, Chhattisgarh. Management combination simulated were three transplanting dates for wet season rice *cv*. Karma Masuri under rainfed and irrigated condition. Thirty three years (1981-2012) weather data (Max T, Min T, Rainfall and Radiation) were collected. The crops standard agronomic practices were followed to grow the crop. Data on plant parameters, like day of maturity, 50% of flowering days, biomass, single grain weight, Straw yield and tiller numbers and instrumental data like radiation, temperature were measured as required for the model input. Phenological stages like emergence, 50% flowering, tillering, grain filling, anthesis, maturity and harvesting were recorded from the field.

The Decision Support System for Agro-technology Transfer (DSSAT v.4.5) was used to calibrate pertinent genetic coefficient and to validate it for the said rice variety in the Raipur (Chhattisgarh) situation (Table 1). The DSSAT is a software package integrating the effects of soil, crop phenotype, weather and management practices on crop growth and yield. It has been in use for more than fifty years by researchers in over 100 countries. The user can simulate multi-year outcomes of crop management studies for different crops at any location in the world.

For calibration and validation part the actual data of Raipur observatory was used along with field experimental data. For future weather scenario, DSSAT v.4.5 output was used. The decision support system for agrotechnology transfer (DSSAT) was originally developed by an international network of scientists, cooperating in the International Benchmark Sites Network for Agrotechnology Transfer project (Jones *et al.,* 1998), to facilitate the application of crop models in a systems approach to agronomic research. It is a regional climate modeling system and can be applied to any area of the globe (Hudson and Jones, 2002) to generate detailed climate change projection. All the projected files contain usual meteorological parameters such as maximum temperature, minimum temperature, rainfall and radiation. In the data set year wise predicted data is arranged from 2011 and 2012 to 2080. The current standard horizontal resolution of HadRM3P is 0.44° x 0.44° lat/long, giving a grid spacing of 50 km. A 25 km resolution version has also been developed and run over Europe in a 30 year climate change experiment. Boundary conditions for the PRECIS RCM are on a grid of 2.5° latitude x 3.75° longitude, about 300 km resolution at 45N or 400 km at the equator.

Table 1. Genetic coefficients for rice cv. Karma Masuri at Raipur station, IGKV

Name of variety	P1	P2R	P5	P2O	G1	G2	G3	G4
Karma Masuri	690.5	124.8	552.0	9.910	45.51	0.0233	1.00	1.00

P1- Time period (expressed as growing degree days, GDD), P2R- Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in ^{0}C), P5-Time period (in GDD^{0}C), P2O-Critical photoperiod or the longest day length (hours), G1: Potential spikelet number coefficient, G2- Single grain weight (g), G3- Tillering coefficient (scalar value), Temperature tolerance coefficient (Usually 1.0 for variety, grown in normal environment)

Table 2. Layer wise soil physical and chemical properties of the experimental site

Soil layer (cm)	SLLL	SDUL	SSAT	SRGF	SSKS	SBDM	SLOC	SLCL	SLSI
5	0.237	0.449	0.572	1	0.14	1.32	1.132	48	21.5
15	0.237	0.449	0.572	1	0.14	1.32	1.132	48	21.5
30	0.241	0.475	0.589	0.638	0.1	1.45	0.298	53.5	16
45	0.285	0.511	0.63	0.472	0.08	1.5	0.238	54.5	15.5
60	0.251	0.49	0.613	0.35	0.08	1.55	0.179	54	17.5
90	0.303	0.528	0.642	0.223	0.05	1.6	0.238	55	15.5

SLLL - Lower limit moisture (cm^3 cm^{-3}.), SDUL - Upper limit moisture, drained (cm^3 cm^{-3}), SSAT - Upper limit moisture, saturated (cm^3 cm^{-3}), SSKS - saturated hydraulic conductivity, SBDM - Bulk density, moist (g cm^{-3}), SLOC - Organic carbon (%), SLCL - Clay (<0.002 mm, %), SLSI - Silt, (0.05 to 0.002 mm, %)

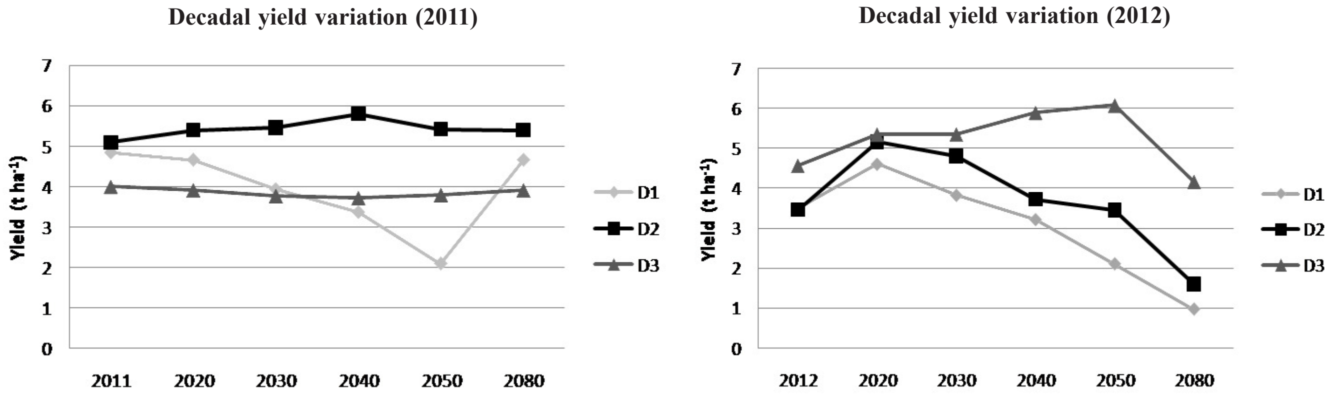


Fig. 1. Decadal yield variation

Layer wise soil physical and chemical properties used in this model (Table 2). The fertilizer (NPK) was used in the ratio of 100:60:40 for all the treatments and irrigation was applied as needed. The experiment was laid out in randomized block design (RBD) with three replications for three dates of sowing *viz.* 11th June, 21th June and 29th June during 2011 and 10th June, 15th June and 22th June during 2012 in locally popular medium duration varieties Karma Masuri.

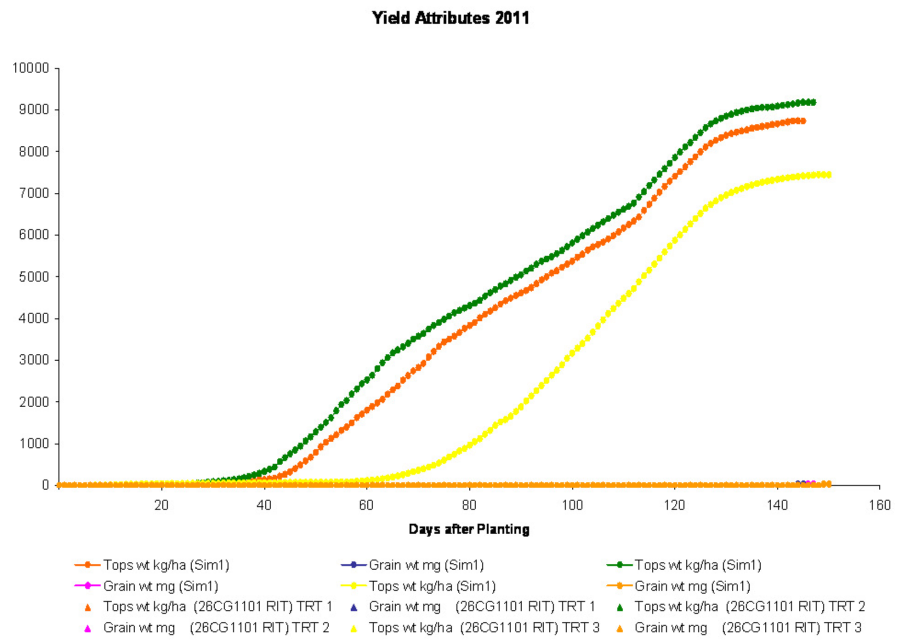
RESULTS AND DISCUSSIONS

By running the model, it was observed that in Raipur region the overall predicted yield among three different dates (11th June, 21th June and 29th June 2011) of sowing, the second date (21th June 2011) of sowing gave higher yield 5.09, 5.39, 5.46 and 5.80 t ha^{-1} for the year 2011, 2020, 2030 and 2040, respectively. The trend analysis is done by considering current year as a base year value. Trend shows overall increasing yield in second date of sowing with yield increases by 0.30 t ha^{-1} and 0.70 t ha^{-1} from the present yield (5.09 t ha^{-1}) for the year 2020 and 2040, respectively.

On the other hand increasing trend of yield has been observed in 2012 at third date of sowing (10th June, 15th June and 22nd June 2012). It was observed that higher yield of 17.17%, 17.22%, 29.09% and 33.14 % compared to current year yield of 4.56 t ha^{-1} in 2020, 2030, 2040 and 2050, respectively then decreasing by 8.87%. The simulated phenology and yield were found in agreement with observed one suggesting that calibration model may be operationally used with routinely observed soil, crop and weather parameters. In this region significant deviation has been observed. Thus in central Chhattisgarh, overall positive output in yield with decreasing trend is obviously a matter of great concern. The planners and farmers should be aware of the fact. Low cost adaptation strategies like changing the sowing date, sowing improved variety, etc., may be followed for yield sustainably. The yield attributing characters of rice variety karma masuri are

Table 3. Variation of predicted yield in two different years of Raipur stations of Chhattisgarh

Raipur Agroclimatic Zone	Date of Sowing	Yield (t ha^{-1})						Yield difference compaired with current year (%)				
		2011	2020	2030	2040	2050	2080	2020	2030	2040	2050	2080
Karma Masuri	D1	4.84	4.66	3.93	3.36	2.09	4.66	-3.73	-18.83	-30.52	-56.75	-3.73
	D2	5.09	5.39	5.46	5.80	5.42	5.39	5.91	7.24	13.92	6.40	5.91
	D3	4.00	3.91	3.76	3.71	3.79	3.91	-2.20	-5.80	-7.03	-5.13	-2.20
		2012	2020	2030	2040	2050	2080	2020	2030	2040	2050	2080
Karma Masuri	D1	3.48	4.60	3.82	3.21	2.10	0.96	32.21	9.84	-7.75	-39.62	-72.29
	D2	3.46	5.17	4.80	3.72	3.45	1.58	49.29	38.87	7.57	-0.17	-54.11
	D3	4.56	5.34	5.35	5.89	6.07	4.16	17.17	17.22	29.09	33.14	-8.87



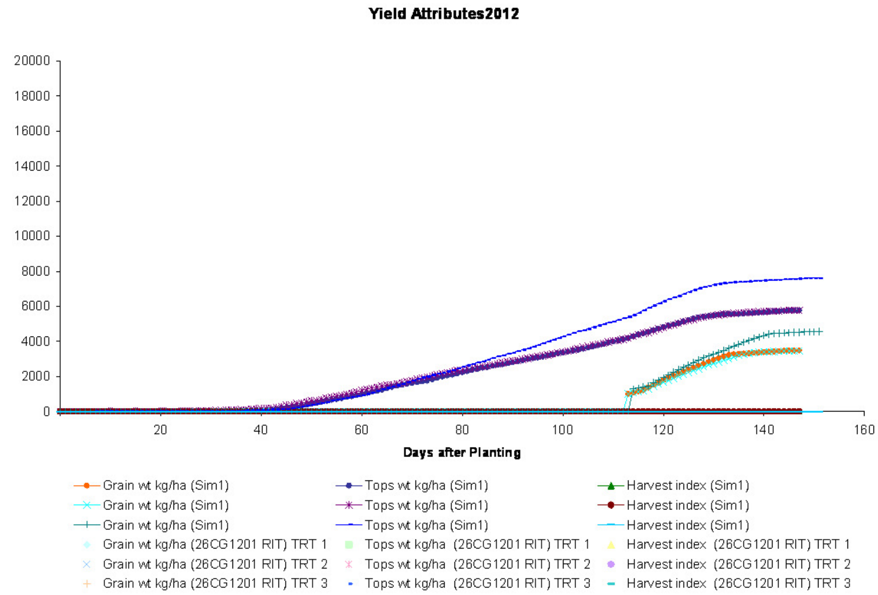
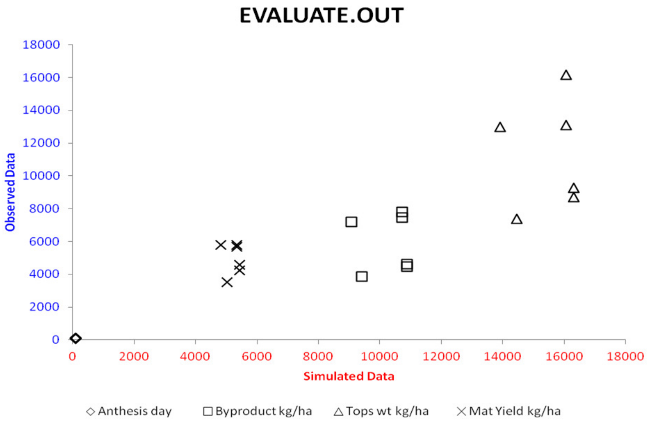


Fig. 2. Yield Attributing Characters



closely associated in anthesis day, by product yield, top weight and maturity yield for simulating the model (Fig. 1).

It may be deduced that the model was found to predict the phenological occurrence of the crop well enough to facilitate the farmers to make broad decision on the crop management operations, which can be directly linked to crop phenology in the DSSAT Rice model. Genotypes of rice variety Karma Masuri was found to have maximum closeness of simulated value over observed at different transplanting dates. The result showed that the early and late sowing dates gives lower yield as compared to optimum sowing dates. The decrement in the yield of rice in early sowing (1st week of July) dates and late sowing (last week of July) may probably be attributed to the increasing temperature in the future. Overall the yield decrement can be observed in central Chhattisgarh.

REFERENCES

Aggarwal PK and Mall RK 2002. Climate change and rice yields in diverse agro-environments of India. II. Effect of uncertainties in scenarios and crop models on impact assessment. Climate Change52:331-43

Baxla AK, Singh PK, Singh KK, Bhan SC and Kumar B 2013. Growing and yield prediction of rice for the climate condition of south Alluvial zone of Bihar using DSSAT rice model, National Symposium on Climate Change and Indian Agriculture: Slicing down the Uncertainties, Abstracts,S6-09 pp-190, 22-23 Jan2013 at CRIDA- ICAR, Hyderabad.

Hudson DA and Jones RG 2002. Regional climate model simulations of present day and future climates of Southern Africa. Bracknell: UK Met Office Hadley Centre.Technical Notes No. 39Wilson, S., Hassell, D., Hein, D., Jones, R and R Taylor. (2005). Installing and using the Hadley Centre Regional Climate Modeling System, PRECIS Exeter: UK Met Office Hadley Center. Version 1.3.

IPCC 2007. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. Van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK., pp 976.

Indian network for climate change assessment INCCA, Report-2, 2011.

International Benchmark Sites Network for Agrotechnology Transfer. 1993. The IBSNAT Decade. Department of Agronomy and Soil Science, College of Tropical Agriculture and Human Resources, University of Hawaii, Honoluly, Hawaii.

Jones JW, G Hoogenboom, CH Porter, KJ Boote, WD Batchelor, LA Hunt, PW Wilkens, U Singh, AJ Gijsman, JT Ritchie 2003. The DSSAT cropping system model Europ. J. Agronomy 18 (2003) 235-265 www.elsevier.com/locate/eja.

Subharanjan Das, Swarup Biswas, Saon Banerjee and Asis Mukherjee 2013. Detecting future yield of *Boro* rice in different stations of West Bengal using DSSAT model, National Symposium on Climate Change and Indian Agriculture: Slicing down the Uncertainties, Abstracts S6-11 pp 191 22-23 Jan 2013 at CRIDA- ICAR, Hyderabad.