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Short communication

Yield gap in rice and wheat productivity in different agroclimatic zones of Punjab

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Rice and wheat are the major staple cereal food in Asia. More than 90% of the world's rice is grown and consumed in Asia, where 60% of the world's population lives. Nevertheless, rice is a choice crop of the millions of poor and small farmers not only for income but also for household food security. Wheat is the main source of energy and nutrition in human diet. In the realm of food crops in the world, wheat (Triticum spp.) occupies the number one position. It is the first important and strategic cereal crop for the majority of world's populations. It is the most important staple food of about two billion people (36% of the world population). India is one of those countries that took full advantage of the plant type based high yielding varieties of rice and wheat since their introduction in the mid-sixties (Aggarwal *et al*, 2008). Both rice and wheat crops are important in India as they play a critical role in food security of the country.

Timsina and Humphreys (2006) reviewed the performance of CERES-Rice and CERES-Wheat in the rice-wheat areas of Asia and Australia and concluded that both models have generally performed well in predicting the dates of phenological events and grain and biomass yield. According to Timsina and Humphreys (2003) a DSSAT/ CERES rice-wheat model offers the ability to evaluate options for increasing yield, water and nitrogen use efficiency of rice-wheat system. Process based crop simulation models can be used to predict the growth, development and yield of crops. In Punjab state the CERES-Rice model (Prabhjyot Kaur and Hundal, 2001) and CERES-Wheat (Hundal and Prabhjyot Kaur, 1997) were used for the prediction of rice and wheat growth and yield in the central irrigated plains of the Indian Punjab.

Using CERES ver. 3.5, Aggarwal *et al* (2000) reported very large gaps of 8 t ha^{-1} for a rice-wheat system in Delhi. They determined potential yield of 16.0 t ha^{-1} (rice 9.0 t ha^{-1} and wheat 7.0 t ha^{-1}) for Delhi using CERES Rice and CERES Wheat as standalone models. These potential yields were much higher than the national average rice-wheat system yields in long-term experiments (8.1 t ha^{-1}) or the Punjab average systems yield (7-8 t ha^{-1}). Prabhjyot-Kaur and Singh (2010) used the CERES-Rice and CERES-Wheat models for rice and wheat, respectively to evaluate the yield gap between actual and potential attainable yield in Punjab state. They reported that the productivity of rice and wheat is highly dependent on prevailing weather, inter-seasonal climatic variability, soil conditions and agricultural inputs.

The objectives of the present study were to apply the calibrated and validated dynamic simulation models for simulating the potential yield of rice and wheat and to quantify the "Yield gaps" for rice and wheat in the state.

Historical data on productivity of rice and wheat crop (1999-2009) was collected from Statistical Abstract, Punjab to evaluate the effect of weather on crop productivity and to quantify the yield gap. The calibrated and validated CERES-Rice and CERES-Wheat model for rice and wheat crops, respectively were run from 1999-2009 and for different Agroclimatic zones of the state (Agroclimatic Zone II - Ballowal Saunkhri; Agroclimatic Zone III - Amritsar, Jalandhar, Ludhiana, Patiala; Agroclimatic Zone IV – Bathinda, Faridkot; and Agroclimatic zone V - Abohar) to obtain the potential yield of crops. The study was based upon assumption that over the past eleven years the contribution of technology changes towards yield gap will be minimum.

The simulated crop yields are expected to capture the deviations in crop yields arising from year-to-year variability in weather conditions. Then the year-wise simulated yields were regressed against time and predictive models were developed for calculating the simulated trend yield. The deviation between simulated from its trend yield shows the likely effect of "Weather" on crop yield. The "Yield Gap" between the actual (with controllable and uncontrollable factors as limiting factor) and potential yields (with only uncontrollable factor as the limiting factor) for rice and wheat crops were identified and quantified.

Table 1 : Model simulated "Yield Gap" between actual and potential yield of wheat and rice crop at different locations in Punjab

Station / Crop year	Rice			Wheat		
	Observed yield (kg ha^{-1})	Simulated trend yield deviation (%)	Yield deviation (%)	Observed yield (kg ha^{-1})	Simulated trend yield deviation (%)	Yield deviation (%)
Ballowal Saunkhri						
2010-11	3576	2.29	1.71	4294	-9.99	-6.56
2011-12	3633	1.76	1.25	4507	-13.20	-8.89
2012-13	3604	-1.64	-1.72	4220	-10.07	-6.62
Jallandhar						
2010-11	3610	6.43	5.31	4690	2.84	2.74
2011-12	3536	6.76	5.60	5062	-1.66	-0.52
2012-13	3790	-1.00	-1.16	4575	2.75	2.68
Ludhiana						
2010-11	4409	3.15	2.46	4964	-1.05	-0.07
2011-12	4257	3.10	2.41	5375	-6.44	-3.98
2012-13	4548	-1.10	-1.25	4853	0.23	0.85
Bathinda						
2010-11	4088	0.34	0.01	4609	3.88	3.50
2011-12	4048	-0.96	-1.13	5000	-4.14	-2.32
2012-13	4513	-1.95	-1.99	4787	-2.72	-1.28
Amritsar						
2010-11	2705	11.35	9.61	4283	2.01	2.14
2011-12	2620	13.24	11.26	4975	-2.49	-1.12
2012-13	2846	8.47	7.09	4654	-1.44	-0.36
Patiala						
2010-11	3730	-2.84	-2.77	4836	-2.30	-0.98
2011-12	3861	-4.97	-4.63	5472	-9.36	-6.10
2012-13	4153	-0.79	-0.98	4798	1.15	1.52
Abohar						
2010-11	3699	6.89	5.72	4660	2.68	2.63
2011-12	3458	6.62	5.48	4996	-8.19	-5.25
2012-13	3960	-2.17	-2.18	4927	1.38	1.69
Faridkot						
2010-11	4047	10.40	8.78	4810	1.14	1.51
2011-12	4014	7.55	6.29	5266	-4.54	-2.60
2012-13	4357	-3.19	-3.07	4730	1.50	1.77

The models for prediction of the "Yield Deviation" in rice and wheat crop arising due to the "Weather variability component" were developed from the simulated trend yield deviations and the observed trend yield deviations. These yield deviation prediction models were used for forecasting the yield deviation arising due to the "Weather variability" and "Yield gap" components. Further the yield deviations computed from these models were used to forecast / predict the yield of rice and wheat crops.

Rice and wheat crop

The CERES-Rice model for rice and CERES-Wheat model for wheat were employed for simulating the past season yield for different agroclimatic zones under the study. The "Yield gap" between the actual and potential crop yield was assessed with the help of the model. The simulated yields are expected to capture the deviations in crop yields arising from year-to-year variability in weather conditions. The results revealed that during the crop year

2007-8 weather variability contributed positively towards rice productivity in whole of the state. The perusal of the data in the graphs indicate that over the past decade for wheat crop the weather variability contributed positively towards wheat yield in Agroclimatic Zone II during the crop year 2002-03, 2005-06, 2007-08 and 2009-10, in Agroclimatic Zone III during the crop year 1999-00, 2000-01 and 2002-03 and in Agroclimatic Zone IV during the crop year 2000-01, 2001-02, 2003-04 to 2005-06, 2007-08 and 2008-09.

Then the year-wise simulated yields were regressed against time and a linear model was developed for calculating the simulated trend yield. The deviation between simulated crop yield from its trend yield shows the likely effect of weather on crop yield. The models for prediction of the "Yield Deviation" arising due to the "Weather variability component" were developed from the simulated trend yield deviations and the observed trend yield deviations.

The models developed for prediction of yield deviations for rice are:

Yield deviation (%) = 0.8719*Simulated trend yield deviation - 0.2897 (R^2= 0.34)

The models developed for prediction of yield deviations for wheat are:

Yield deviation (%) = 0.725*Simulated trend yield deviation + 0.6857 (R^2= 0.67)

These yield deviation prediction models can be used for forecasting the yield deviation arising due to the "Weather variability", "Technology advancement" and "Yield gap" components. Further the models were used to predict the rice and wheat yield for crop year 2010-11, 2011-12 and 2012-13 (Table 1). These models predicted the rice and wheat yield within the range of -3.07 to 11.26 % and -8.89 to 3.50%, respectively.

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