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Yield Gap Analysis Using Oryza 2000 Model in Two Rice Growing Districts of Andhra Pradesh

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Abstract: The study describes the modeling approach in order to estimate the yield gap in Guntur and Nalgonda districts of Andhra Pradesh. ORYZA 2000 model was validated for both districts. Three years of (2007-08 to 2009-10) Guntur and Nalgonda district yields were collected from Directorate of Economics and Statistics andhra Pradesh. Weather information is collected from the meteorological departments of the respective regional research stations was used as input parameters of the model ORYZA 2000 to determine potential yield. The yield gap was estimated as the difference between potential and actual yield. The highest yield gap was recorded in two districts and is related to the management factors and soil related problems. The delay in transplanting (or sowing) of rice is due to delay in rainfall and late release of canal water. The model estimated yield gap of 3410 and 4012 kg ha^{-1} in Guntur and Nalgonda districts, respectively.

Key words: Yield gap · ORYZA 2000 model · Potential yield · Rice crop

INTRODUCTION

As optimum crop production estimation becomes more complex, involving several factors like fertilizer, pest control, genotype, environment and cultural practices, conducting trials with various combinations of these factors into account become very complex and expensive. Crop growth simulation models are the tools which reduce the need for expensive and time consuming field experimentations as they can be used to extrapolate the results of the research conducted in one season or on location to other season, location or management. They also provide a means to quantify the effects of climate, soil and management on crop growth, yield and sustainability of agricultural production [1, 2]. Models are being used to assess how changes in environmental conditions, particularly CO_2 concentration, precipitation and temperature, may affect crop productivity. Rice productivity may be enhanced my minimizing "Research yield gap" (Potential yield - Experimental yield or Attainable yield) and "Management yield gap" (Attainable yield-Actual yield) through improving efficiency with appropriate management practices. The approaches to bridge the gap of projected demand to current level of production could be done through the expansion of rice cultivated area (horizontal expansion), improving yield (vertical expansion), *i.e.* yield gap bridging and reducing yield losses [3]. The yields will vary from one area to another, hence the need to carry out a study to identify the yield gap analysis of rice in Guntur and Nalgonda districts using ORYZA 2000 model.

MATERIALS AND METHODS

The ORYZA 2000 model was calibrated and validated with the data sets generated by with the secondary data collected from Regional Research Stations. The model ORYZA 2000 was used [4], in this study namely by applying the module for potential. ORYZA 2000 uses solar radiation to calculate daily rates of CO_2 assimilation and dry matter accumulation and temperature data as the basis for calculating the rate of phonological development and respiration losses. Nutrient and water supply are considered to be non-limiting factors.

The historical weather data for rice producing areas of Andhra Pradesh state viz. Guntur, Nalgonda and Visakhapatnam districts have been used. The analysis was undertaken for three consecutive years

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(2007-08 to 2009-10) depending upon the availability of weather parameters as required to simulate ORYZA 2000 model.

Potential Yield: Potential yield is defined as the maximum yield of a variety restricted only by the season-specific climatic conditions without limitation of water and nutrients and with optimum cultural management. Model simulated yield for 15th July (optimum transplanting date) was considered as potential yield for three districts.

Actual Yield: The rice yield data for the respective districts as obtained from the reports of The Directorate of Economics and statistics, Hyderabad were considered as actual yield for the respective district.

Attainable Yield Due to Delayed Sowing: Generally paddy-paddy cropping pattern is commonly practiced by the farmers of the Guntur and Nalgonda districts. Due to late release of canal sowing of paddy was delayed than the normal sowing date. Attainable yield was quantified from the yield gap obtained due to delayed sowing. Model simulated rice yield in 1st week of august (transplanting date) was taken as "Attainable" i.e. yield potential for delayed sowing date.

RESULTS AND DISCUSSION

Estimation of Yield Gap in Guntur District

Actual Yield: Guntur is potential rice producing district of Krishna-Godavari zone. Deep black soils coupled with good irrigation potential by canals in the district are the major yield optimizing factors for the district to be the highest rice producer in the state. The reported actual rice yields of Guntur district ranged from 3408 to 3586 kg $ha^{-1}$with an average of 3480 kg ha^{-1} for the period 2007 to 2009. During the year 2009, the highest actual yield (3586 kg ha-1) was recorded, which was comparable to the yields of irrigated rice in Andhra Pradesh. The increasing actual yields could be attributed to the high irrigation potential of canals. The productivity of rice has shown either increase or stagnation. The data on past crop performance during several years suggest that year to year variation of rice growth and development mostly due to weather changes particularly in the temperature and rainfall [5].

Potential Yield: The variability in simulated potential yield of irrigated rice is a reflection of climatic conditions particularly radiation, maximum and minimum temperatures during the crop growth period. The potential yield of paddy simulated by ORYZA 2000 model at Guntur ranged from 6148 kg ha^{-1} (2007) to 7705 kg ha^{-1} (2009) with an average value of 6889 kg ha^{-1}. The potential for the Guntur district simulated by the model was 1.71 to 2.24 times higher than actual yield with a mean value 1.98 since the potential conditions were assumed to be free of biotic and abiotic stresses. The potential yield as simulated by model was for the period 2007 to 2009 found significant at Guntur, it showed the decreasing trend.

The model simulated highest yield in the year 2009 and did not match with the actual yield because July 2nd week was considered as optimum period for transplanting in modeling, but majority of the farmers might have taken up transplanting of paddy up to month end of august. Thus these results conveyed the message that, other condition being assumed constant the variation was due to weather elements.

Attainable Yield: The various management factors play an important role in estimation of attainable yields. The management constraint was late transplanting (July 2nd week onwards), a common practice by farmers for several reasons, particularly due to irregular canal water supply. Planting time has significant influence on grain yield of rice. In general, transplanting in the first fortnight of July gives best yield in kharif. Delay in planting by 15-20 days from optimum transplanting time reduced grain yield by 15-20 percent and two months delay by 50-75 percent at several places. The attainable yield for late sowing simulated by the model ranged from 4947 kg ha^{-1} (2009) to 6385 kg ha^{-1} (2007) with an average of 5768 kg ha^{-1}. The variation in attainable yield is found to be significantly and followed similar trend as that of potential yield. The lower attainable yield as estimated by the model was only due to delayed sowing [6]. The low and highly fluctuating amounts of solar radiation received during reproduction and /or ripening phases of kharif plantings was responsible for low and highly variable yield [7]. Some times due to heavy rains occur in September and October months in Coastal districts, the crop was damaged completely or partially.

Total Yield Gap: The total yield gap (potential-actual) as simulated by ORYZA 2000 rice model was 3410 kg ha^{-1} (Table 1) ranging from 2562 kg ha^{-1} (2009) to 4260 kg ha^{-1} (2007). The yield gap is used as a tool to recognize and prioritize target. The first step in narrowing the yield gap is therefore to identify and analyze actual and potential constraints to r ice production in a particular area [8].

Table 1: Estimation of yield gap in rice production for Guntur district

	Yield (kg ha^{-1})			Yield (kg ha^{-1})		
	Potential	Attainable	Actual	Total	Management	Sowing
2007	7705	6385	3445	4260	2940	1320
2008	6815	5973	3408	3407	2565	842
2009	6148	4947	3586	2562	1361	1201
Mean	6889	5768	3480	3410	2289	1121
SD	781	741	94	849	825	249
CV	11.3	12.8	2.7	24.9	36.0	22.2

Table 2: Estimation of yield gap in rice production for Nalgonda district

	Yield (kg ha^{-1})			Yield (kg ha^{-1})		
	Potential	Attainable	Actual	Total	Management	Sowing
2007	7007	6324	3166	3841	3158	683
2008	7359	6581	3111	4248	3470	778
2009	7182	6674	3235	3947	3439	508
Mean	7183	6526	3171	4012	3356	656
SD	176	181	62	211	172	137
CV	2.5	2.8	2.0	5.3	5.1	20.9

Wide range of yield gaps around the world, with average yields ranging from roughly 20 per cent to 80 per cent of yield potential was also reported by Lobell *et al.* [9].

Management Gap: This is defined as the yield gap between attainable yield at late sowing and actual yield. The management gap for the Guntur district as simulated by the model ranged from 1361 kg ha^{-1} (2009) to 2940 kg ha^{-1} (2007) with an average of 2289 kg ha^{-1}. The estimated management gap was 2289 kg ha^{-1} with the CV 36.0 per cent. The higher the CV value indicated the variability in weather, more so the temperature, the most influencing factor in rice production. The management gap was found to be significant and showed a decreasing trend clearly suggesting the good and timely management operations followed by farmers.

Sowing Gap: This is defined as the difference between potential yields and attainable yield due to delayed transplanting. The sowing gap for Guntur district varied from 842 kg ha^{-1} (2008) to 1320 kg ha^{-1} (2007) with an average of 1121 kg ha^{-1}. Patel *et al.* [10] also reported wheat yield gap of 672 kg ha^{-1} due to delay in sowing in Anand, Gujarat.

Estimation of Yield Gap in Nalgonda District

Actual Yield: Nalgonda is potential rice producing district of Southern Telangana zone. Nalgonda district occupied 6th position in area (147 thousand ha), 5th position in production (420 thousand tonnes) and 4th position in terms of productivity (2839 kg ha^{-1}). The area is irrigated with canals, wells and tanks and is the major yield optimizing factors for the district to be the highest rice producer in the state. The reported actual rice yields of Nalgonda district ranged from 3111 to 3235 kg ha^{-1}with an average of 3171 kg ha^{-1} for the period 2007 to 2009. During the year 2009, the highest actual yield (3235 kg ha^{-1}) was recorded, which was comparable to the yields of rice in Andhra Pradesh. The increase in actual yield could be attributed to high irrigation potential of canals.

Potential Yield: The potential yield of paddy simulated by ORYZA 2000 model at Nalgonda ranged from 7007 kg ha^{-1} (2007) to 7359 kg ha^{-1} (2008) with an average value of 7183 kg ha^{-1}. The potential yield in Nalgonda district simulated by the model was 2.2 to 2.4 times higher with a mean value of 2.3 higher than actual yield since the potential conditions were assumed to be free of biotic and abiotic stresses. The potential yield of rice have shown the stagnation / decline as evidenced from a recent analysis of several long term experiments carried out throughout Asia [11]. Similar results were observed by Akula [12] when simulation carried out through WTGROWS and INFOCROP model at Anand for wheat.

Attainable Yield: The various management factors play an important role in estimation of attainable yields. The management constraint was late sowing (July 2nd week onwards), a common practice by farmers for several reasons, particularly due to irregular canal water supply. The attainable yield for late sowing simulated by the model ranged from 6324 kg ha^{-1} (2007) to 6674 kg ha^{-1} (2009) with an average of 6526 kg ha^{-1}. Hassan *et al.* [13] also indicated that the IR-6 transplanted on 25th June obtained higher paddy yield compared to transplanting of paddy on 15th July. These findings are in agreement with those reported by Mohammad *et al.*[14] and Mannan *et al* [15] resulted higher yields were obtained with optimum transplanting date compared to late or early transplanted date.

Total Yield Gap: The average yield gap (potential-actual) as simulated by ORYZA 2000 rice model was 4012 kg ha^{-1} (Table 2) ranging from 3841 kg ha^{-1} (2007) to 4248 kg ha^{-1} (2008). Timsina *et al.* [1] estimated that wide gaps between potential, research station and farmer yields. The gaps between potential and research station yields ranged from 28 to 38% of potential yield or 3.0 to 3.8 t/ha. The gap between potential and on-farm yields was even greater (48-68%) at all locations. Pathak *et al.* [5] estimated similar potential yields of rice using CERES Rice V 3.0 for various locations in NW India.

Management Gap: This is defined as the yield gap between attainable yield at late sowing and actual yield. The management gap for the Nalgonda district as simulated by the model ranged from 3158 kg ha^{-1} (2007) to 3470 kg ha^{-1} (2008) with an average of 3356 kg ha^{-1}. The management gap clearly suggesting the poor and untimely management operations followed by the farmers for one or other reasons. Long-term experiments conducted in the Indo-Gangetic plains showed a large decline in rice yields and the simulation results indicated that the rate of decline was related to the initial yield of crops. The results indicate that there are only limited management options for increasing yields of rice [16].

Sowing Gap: This is defined as the difference between potential yields and attainable due to delayed sowing by 15 days. The sowing gap for Nalgonda district varied from 508 kg ha^{-1} (2009) to 778 kg ha^{-1} (2008) with an average of 656 kg ha^{-1} with the CV of 20.9 per cent. The higher the CV value indicated the variability in weather, especially in rainfall which is the source for sowing of rice nurseries. Kamran Nahar *et al.* [17] reported that significant reduction in yield of late transplanted rice due to increase in spikelet sterility at panicle emergence stage due to low temperature.

CONCLUSIONS

Bridging the yield gap requires integrated and holistic approaches and adequate institutional support to farmers. Mechanization, timely release of canal water and proper management of pests and diseases will help in bridging the yield gaps. For this purpose institutional and policy support to farmers is crucial for ensuring agricultural input supplies, farm credit and minimum support price in a holistic approach for sustainable increase in rice production. This will help in ensuring food and nutritional security in future.

REFERENCES

1. Timsina, J., H. Pathak, E. Humphreys, D.C. Godwin, B. Singh, A.K. Shukla and U. Singh, 2004. Evaluation of yield gap analysis in rice using CERES-Rice in northwest India. Proceedings of 4th Int. Crop Science Congress. Brisbane, Australia, 26 Sept-10 Oct 2004.
2. Sarkar, R. and S. Kar, 2006. Evaluation of management strategies for sustainable rice-wheat cropping systems, using DSSAT. Journal of Agricultural Sciences, 144: 121-134.
3. Chaudhary, R.C. and D.V. Tran, 1999. Can Africa be the future rice supplier for Asia? In: Proc. 4th Asian International Rice Conference, Cebu, Philippines. pp: 29.
4. Bouman, B.A.M., M.J. Kropff, T.P. Tuong, M.C.S. Wopereis, H.F.M. Ten Berge and H.H. Van Laar, 2001. ORYZA 2000: Modeling Lowland Rice. International Rice Research Institute, Wageningen University and Research Centre, Los Baños, The Philippines, Wageningen, The Netherlands, pp: 235.
5. Pathak, H., J.K. Ladha, P.K. Aggarwal, S. Peng, S. Das, Yadvinder Singh, Bijay Singh, Kamara, S. K. Mishra, B. Sastri, A.S.R.A.S. Aggarwal, H.P. Das, D.K. and R.K. Gupta, 2003. Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. Field Crops Research. 80: 223-234.
6. Patel, H.R. and A.M. Shekh, 2006. Yield gap and trend analysis of wheat using CERES-wheat model in three districts of Gujarath state. Journal of Agrometerorology. 8(1): 28-39.
7. Venkanna. 1999. Effect of climate on growth and yield of certain lowland rice varieties in Andhra Pradesh. Ph.D. *Thesis,* Acharya N G Ranga Agricultural University, Rajendranagar, Hyderabad, India.
8. Dat Van Tran. Closing the rice yield gap for food security [On-line]. In : Chataigner J. (ed.). The new development in rice agronomy and its effects on yield and quality in Mediterranean areas. Montpellier : CIHEAM, 2001. p. Available (Cahiers Options Méditerranéennes; n. 58)
9. Lobell, D.B., K.G. Cassman and C.B. Field, 2009. Crop yield gaps: Their importance, magnitudes and Causes. The Annual Review of Environmental and Resources. 2009. Accessed at arjournals. Annualreviews. org. 34: 179-204.
10. Patel, V.J., H.R. Patel and Vyas Pandey, 2008. Estimation of yield gap in Anand and panchamahal district using CERES-wheat model. Journal of Agrometeorology. Special Issue part-II 393-397.
11. Regmi, A.P., J.K. Ladha, H. Pathak, E. Pasuquin, C. Bueno, D. Dawe, P.R. Hobbs, D. Joshy, S.L. Masky and S.P. Pandey, 2002. Analysis of yield and soil fertility trends in a 20- year rice-wheat experiment in Nepal. Soil Science Society of American Journal. 66: 857-867.
12. Akula, B., 2003. Estimating wheat yields in Gujarat using WTGROWS and INFOCROP models. Ph.D. thesis submitted to GAU, Sardar krishinagar.

13. Hassan, G., N.U. Khan and Q.N. Khan, 2003. Effect of transplanting date on the yield and yield components of different rice cultivars under high temperature of D.I. Khan. Sci. Khy., 16(2): 129-137.
14. Mohammad Safdar Baloch, Inayat Ullah Awan and Gul Hassan, 2006. Growth and yield of rice as affected by transplanting dates and seedlings per hill under high temperature of Dera Ismail Khan, Pakistan. J. Zhejiang Univ. Sci. B., 7(7): 572-579.
15. Mannan, M.A., M.S.U. Bhuiya, S.M.A. Hossain and M.I.M. Akhand, 2009. Study on phenology and yielding ability of basmati fine rice genotypes as influenced by planting date in aman season. Bangladesh J. Agril. Res., 34(3): 373-384.
16. Aggarwal, P.K., S.K. Bandyopadhyay, H. Pathak, N. Kalra, S. Chander and S.S. Kumar, 2000. Analyses of yield trends of the rice-wheat system in north-western India. Outlook Agric., 29(4): 259-268.
17. Kamrun Nahar. Mirza Hasanuzzaman. Ratna Rani Majumder. 2009. Effect of low temperature stress in transplanted aman rice varieties mediated by different transplanting dates. Academic Journal of Plant Sciences, 2(3): 132-138.