SIMULATING RICE YIELD IN RIO GRANDE DO SUL STATE WITH A PROCESS-BASED MODEL

Nereu Augusto Streck[1]; Hamilton Telles Rosa[2], Lidiane Cristine Walter[3]; Simone E. Teleginski Ferraz[4], Haroldo Fraga de Campos Velho[5], Stefanía Dalmolin da Silva[6]

Key words: productivity, modeling, InfoCrop.

INTRODUCTION

Rice constitutes the staple food of about half of the word population. Brazil is the largest rice producer outside Asia, with about 2.9 million ha grown annually (USDA, 2010). Rio Grande do Sul state is the largest producer in Brazil, with about 1.3 million ha grown annually in a flooded system, that produces about 60% of the rice harvested in the country (IRGA, 2009).

Crop simulation models are important tools both for scientists and for decision-makers. Currently, there are simulation models for virtually all major agricultural crops. Crop models vary in complexity from very simple empirical statistic-based models to very complex process-based models. For rice, InfoCrop is a recent process-based model with intermediate complexity developed in India (AGGARWAL et al., 2006a). Among advantages of InfoCrop over previous more complex process-based models, such as the Oryza model (KROPFF et al., 1994), is that the former is composed by more general and robust response functions and parameter/indices for representing plant processes and mechanisms than the latter. An example of robust parameter is the Radiation use efficiency (RUE) which is used in InfoCrop as a surrogate of the complex photosynthesis pathways used in Oryza model. More general and robust approaches are advantageous because they require less and more easily measured coefficients and inputs.

The InfoCrop model has not been tested or used in Brazilian Rice ecosystem, which constituted the rationale for this effort. The objective of this study was to adapt and test the InfoCrop model for simulating rice grain yield in the different rice producing regions of the Rio Grande do Sul State.

MATERIAL AND METHODS

The model used in this study to simulate rice grain yield is the InfoCrop model (AGGARWAL et al., 2006a). InfoCrop is a process-based model that calculates crop growth on a daily basis based on RUE. Partitioning of daily dry matter among roots and shoots is dependent upon developmental stage from crop emergence to physiological maturity. Crop development is calculated using the thermal time approach. Inputs for running the model include daily air minimum e maximum temperature, solar radiation, precipitation, relative humidity, soil properties and cultivar-dependent coefficients. In the study, we input air temperature and solar radiation which are major environmental drivers of rice growth and yield in Rio Grande do Sul State. The cultivar selected was IRGA 417, an early, modern, high-yield and well adapted rice cultivar for cultivation in the State.

The model was run during 13 growing seasons (from 1995/96 to 2005/06) for each of the six regions for rice production in Rio Grande do Sul State (Figure 1). These regions have been defined by the Instituto Rio Grandense do Arroz (IRGA) and are different in terms

[1] Eng. Agrônomo, Prof. PhD, Departamento de Fitotecnia, Avenida Roraima, nº 1.000, Camobi, CEP 97105□900, Santa Maria – RS. nstreck@yahoo.com.br
[2] Eng. Agrônomo, Doutorando do Programa de Pós Graduação em Agronomia, UFSM, hamiltontellesrosa@gmail.com
[3] Eng. Agrônoma, Doutoranda do Programa de Pós Graduação em Engenharia Agrícola, UFSM, lidianewalter@gmail.com
[4] Física, Departamento de Física, UFSM, simonetfe@gmail.com
[5] Eng. Químico, Instituto Nacional de Pesquisas Espaciais, INPE, haroldo@lac.inpe.br
[6] Estudante de Graduação em Meteorologia, UFSM, tefa.ds@hotmail.com

of temperature and solar radiation availability. Three sowing dates were considered (09/20, 10/20 and 11/30) corresponding to early, intermediate and late sowing dates according to the Agroclimate zoning for rice in Rio Grande do Sul (SOSBAI, 2010), respectively. Daily minimum and maximum air temperature and solar radiation throughout the growing season were obtained with the RegCM model of NCAR (National Center for Atmospheric Research) from the Mesoscale Model version 4. RegCM is a comprehensive, finite difference, hydrostatic and in sigma vertical coordinate model, it uses a “split-explicit” approach for time integration, it includes an algorithm to reduce horizontal diffusion when intense topography gradients are in place, and soil-plant-atmosphere integration processes are described by the BATS (Biosphere-Atmosphere Transfer Scheme).

Observed annual rice yield (kg ha^{-1}) for each of the six regions were obtained from the database maintained by IRGA and available at www.irgars.gov.br simulated annual rice yield was the average of the simulated yield on the three sowing dates. The statistic used as a measure of the model performance was the root mean square error (RMSE), with unit of Kg ha^{-1}. The lower the RMSE the better the model predictions.

Figure 1. The regions for rice product0ion in the Rio Grande do Sul State Brazil: 1 – Fronteira Oeste; 2 – Campanha; 3 – Depressão Central; 4 – Planície Costeira Interna à Lagoa dos Patos; 5 – Planície Costeira Externa à Lagoa dos Patos; 6 – Zona Sul. Source: IRGA.

RESULTS AND DISCUSSION

The simulated and observed rice grain yield in each growing season during the period from 1995 to 2006 for each of the six rice regions is in Figure 2. The RMSE varied from 493.3 kg ha^{-1} (Zona Sul region) to 1217.4 kg ha^{-1} (Fronteira Oeste region). Overall, the InfoCrop model captured the interannual variation of the rice yield in the six regions. Interannual variability in rice yield in Rio Grande do Sul State is related to solar radiation availability, which in turn is highly related to the El Niño Southern Oscilation (ENSO) phenomenum (WALTER, 2010). During the warm phase of ENOS (El Niño) precipitation is above normal (solar radiation is below normal) in Rio Grande do Sul. Therefore, the highest rice yields in the State are obtained in La Niña and Neutral years whereas the lowest rice yields are observed during El Niño years.

Among the regions, simulated rice yield was closer to observed yield in the regions Zona Sul, Depressão Central and Planície Costeira Interna à Lagoa dos Patos (RMSE for these regions varied from 493.3 to 639.6 kg ha^{-1}). Simulations were more off for the Fronteira Oeste and Planície Costeira Externa à Lagoa dos Patos regions (RMSE: 1217.4 and 891.8 kg ha^{-1}, respectively), but acceptable because the overall trend and variability of yield among regions was captured by the model. However, more effort has to be dedicated to understand why the simulations were the worst in these two regions. Aside from these particular results, the overall results indicate that the InfoCrop model is suitable for predicting rice grain yield in the Rio Grande do Sul State.

The greatest RMSE values of simulated yield in the Fronteira Oeste and Planície Costeira Externa regions correspond to an error of 20 and 17%, respectively of the average observed yield in the period. For the other regions, the RMSE correspond to about 10%, which is an acceptable error. In India, the error in the simulation with the InfoCrop model was 8.3% (AGGARWAL et al., 2006b), which is slightly lower than the average error of about 14% in our study considering all regions. The greater error of the simulation with the InfoCrop model in the Rio Grande do Sul compared to India may be related to the distinct rice cultivars in these two locations. Some calibration was done for Brazilian rice cultivars, but a few coefficients were kept from the original version of the model, because of the lack of data for local genotypes. Further refinements of the InfoCrop model are under may aiming to improve it's the performance for Brazilian rice genotypes.

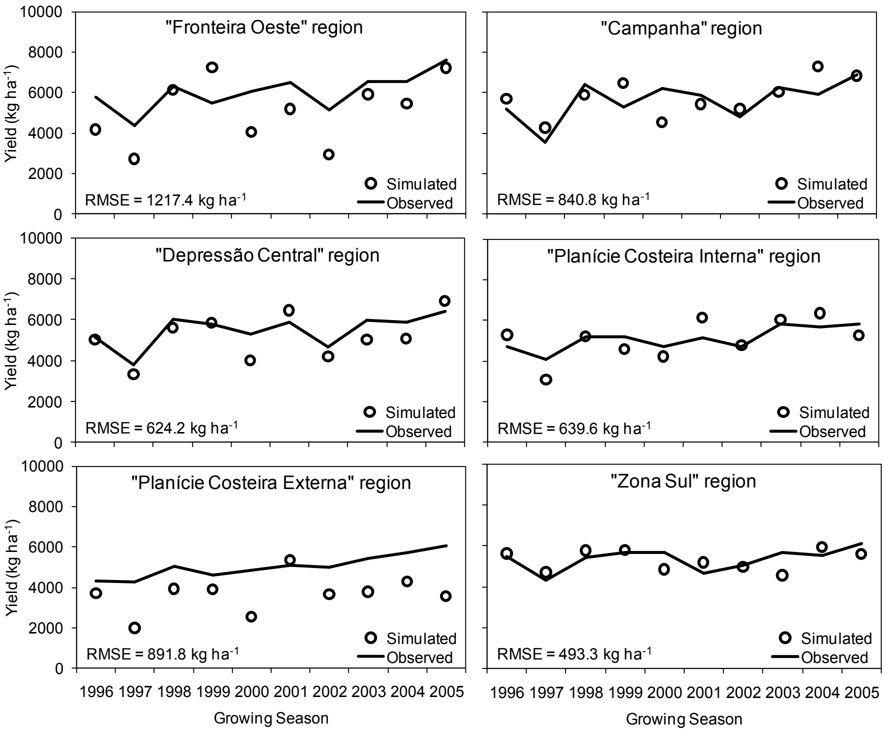

Figure 2. Observed and simulated rice grain yield with the InfoCrop model in six regions of the Rio Grande do Sul State, Brazil, during the period from 1996/97 to 2005/06. RMSE = Root mean square error.

CONCLUSION

The InfoCrop model is suitable and can be used to simulate grain yield in the different rice production regions of the Rio Grande do Sul State.

ACKNOWLEDGMENTS

To the CLIMARS (FINEP/CNPq) project for financial support.

REFERENCES

AGGARWAL, P. K. et al. InfoCrop: A dynamic simulation model for the assessment of crop yields, losses due to pests, and environmental impact of agro-ecosystems in tropical environments. I. Model description. **Agricultural Systems**, Netherlands, v. 89, p. 1-25, 2006a.

AGGARWAL, P. K. et al. InfoCrop: A dynamic simulation model for the assessment of crop yields, losses due to pests, and environmental impact of agro-ecosystems in tropical environments. II. Performance of the model. **Agricultural Systems**, Netherlands, v. 89, p. 47-67, 2006b.

INSTITUTO RIO GRANDENSE DO ARROZ - IRGA. **Dados de safra**. Porto Alegre, 2009. Disponível em: <http://www.irga.rs.gov.br/index.php?action=dados_safra>. Acesso em: 20 out. 2009.

KROPFF, M. J.; Van LAAR, H. H.; MATTHEWS, R. B. ORYZA1: an ecophysiological model for irrigated rice production. In: **SARP Research Proceedings**. Los Banos, Philippines: International Rice Research Institute - IRRI, 1994. 110 p.

SOCIEDADE SUL BRASILEIRA DE ARROZ IRRIGADO. **Arroz irrigado:** Recomendações técnicas da pesquisa para o sul do Brasil. Bento Gonçalves: SOSBAI, 2010. 188 p.

UNITED STATES DEPARTMENT OF AGRICULTURE, Foreign Agricultural Service. **Production, Supply and Distribution Online:** Custom Query. USDA, 2010. Disponível em: <http://www.fas.usda.gov/psdonline/psdQuery.aspx>. Acesso em: 15 mar. 2010.

WALTER, L.C. **Simulação do rendimento de grãos de arroz irrigado em cenários de mudança climática**. 2010. 69 p. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal de Santa Maria, Santa Maria, 2010.