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MAPPING THE POTENTIAL YIELD OF UPLAND RICE IN RONDONIA STATE

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ABSTRACT: The rice farming has a high socioeconomical importance for Brazilian population, and represents since the 1970's, it is the main crop for agricultural borders opening. Aiming characterize the potential yield and to define the regions most favorable for growth upland rice, it was simulated the potential grain yield (PGY), potential evapotranspiration (ETP) and maximum transpiration (TRC) by anoriented process crop model. The simulations were based on cultivar BRSPrimavera, considering eight planting dates (Nov 1st, 10th, 20th, Dec 1st, 10th, 20th, 30th and Jan 9th), for 33 years of data weather (1980-2013), in seven locations at Rondônia state: Ariquemes, Cacoal, Guajara-Mirim, Ji-Paraná, Machadinho do Oeste, Porto Velho and Vilhena. The upland rice crop cycle ranged from 95 days from emergence (DAE) in Ariquemes to 99 DAE in Machadinho do Oeste. The PGY, ETP and TRC data set were spatialized for the region. Rondônia showed an average and standard deviation potential yield of 4393 and 477 kg ha^{-1}. The average ETP was 584,8 mm/cycle, with variance of 1259.9 mm/cycle. Maximum and minimum values of ETP was found for Guajara-Mirim and Vilhena, planting dates of Nov 1st and Jan 9th, respectively. The spatialization of results demonstrated a trend of PGY reduction as the sowing date is delayed. The highest potential yield were found at Vilhena (4952.7 kg/ha) and Ariquemes (4461.4 kg/ha).

KEYWORDS: oryza, production, evapotranspiration

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MAPEAMENTO DA PRODUÇÃO POTENCIAL DO ARROZ DE TERRAS ALTAS NO ESTADO DE RONDÔNIA

RESUMO: A cultura do arroz possui elevada importância socioeconômica para a população brasileira, e representa desde os meados dos anos 70, o principal cultivo responsável pela abertura de fronteiras agrícolas.Com o objetivo de caracterizar o potencial produtivo e delimitar as regiões mais aptas a este cultivo, foi realizada a simulação da produtividade potencial de grãos (PGY), da evapotranspiração potencial (ETP) e da transpiração máxima(TRC) utilizando um modelo de crescimento de cultura. As simulações foram realizadas com a cultivar BRSPrimavera em oito épocas de plantio (01/nov, 10/nov, 20/nov, 01/dez, 10/dez, 20/dez, 30/dez e 09/jan) utilizando 33 anos de dados climáticos (1980-2013) de sete municípios do estado de Rondônia: Ariquemes, Cacoal, Guajara-Mirim, Ji-Paraná, Machadinho do Oeste, Porto Velho e Vilhena. O ciclo do arroz de terras altas variou de 95 dias em Ariquemes à 99 dias em Machadinho do Oeste. Os dados de PGY, ETP e TRC foram espacializados para a região. Rondônia apresentou uma média e um desvio padrão da produção potencial de 4393,8 e 477,37 kg ha^{-1}, respectivamente.A média de ETP para o estado foi de 584,8 mm $ciclo^{-1}$, com variância de 1259,9 mm $ciclo^{-1}$. Os valores de máximo e mínimo de ETP foram encontrados em Guajara-Mirim e Vilhena, para as datas de plantio de 01/nov e 09/jan, respectivamente. A espacialização dos resultados obtidos demostrou uma tendência geral de redução de PGY conforme o atraso no período de semeadura. Os maiores potenciais de produção foram encontrados em Vilhena (4952,7 kg ha^{-1}) e Ariquemes (4461,4 kg ha^{-1}).

PALAVRAS-CHAVE: oryza, produção, evapotranspiração

INTRODUCTION

Rice production in many countries is considered one of the most important social and economical activity, feeding about 50% of global population. Worldwide, 14 million hectares are cultivated with the upland rice (ULR) system, corresponding to 4% of total rice production (Pandey et al., 2006a).

Brazil is the biggest producer country outside Asia, the total production was 11,550 million tons (FAO, 2015). However, only 21% of this production comes from to ULR systems (Embrapa, 2012).

The crop is commonly seen as a subsistence activity planted by poor farmers, but in Brazil, there were more than 5 million hectares of upland rice areas under mechanized cultivation (Gupta & Toole, 1986), number that has been decreasing over the years, once there is no much new areas to open nowadays in the country (Conab, 2014).

The brazilian state of Rondônia has your rice production exclusively in ULR system, where their 52 municipalities are producers, with a total of 134.834 tons in 2014, being the 3rd state in the north country, with the biggest production, corresponding to 1,1% of rice produced in Brazil (Conab, 2015).

Compared with the entire Brazilian rice production, the percentage amount in Rondônia is considerably low. However, considering the main way of production in this region and the potential for agriculure in the north of Brazil (MAPA, 2012), especially in that state, several studies can be conducted to aim explore the potential production for this region.

A valuable way to evaluate this potential is the use of Crop System Models (CSM)to simulate the yield in good conditions for this crop (Bouman et al., 2001a).The use of CSM is well applied in the modern agriculture, as anuseful tool for decision making (Jones et al., 2003), condensing some agronomic aspects about biological process interacting with many aspects related to the crops through mathematical equations (van Ittersum, 2003). Regarding the possibilities, those tools also can help in the spatialization of potential production for upland rice crops, and give some information related to the best yield results for each location (Heinemann, 2002), in Rondônia state.

The aim of this study wasmap the potential yield, through of data related to climatic aspects, in different sowing dates and locations of Rondônia, using a CSM to provide information and support the decision make related to improvement in the upland rice crops at this location.

MATERIAL AND METHODS

To assessment the potential for ULR production at the Brazilian state of Rondônia, we used 33 years of weather data from Ariquemes (-9.91° S, -63.40° W), Cacoal (-11.43° S, -61.46° W), Guajara-Mirim (-10.79° S, -65.32° W), Ji-Parana (-10.88° S, -61.94° W), Machadinho D'Oeste (-9.40° S, -61.97° W), Porto Velho (-8.76° S, -63.86° W), and Vilhena (-12.74° S, -60.12° W). Simulations were processed by CSM ORYZA2000 (Bouman et al., 2001). Were simulated the croppotential yield (PGY, kg ha^{-1}), potential

evapotranspiration (ETP, mm), maximum transpiration (TRC, mm) and days between sowing date to maturity for each location.

ORYZA2000 is an ecophysiological model, which simulates growth and development of rice including the daily biomass balance as a function of genotype parameters integrating the water demand, the uptake and translocation of nitrogen and CO_2assimilation by vegetal organs in every type of rice ecosystems (Bouman et al., 2001a). Developed by the University of Wageningen and the International Rice Research Institute, this CSM can be used for many purposes, initially applied to irrigated rice crops (Bouman& van Laar, 2006), but allows to be modified to accept upland rice routines (Kreyeet al., 2009). Bouman et al. (2001b) give a detailed description of these routines, input datas and the tools of the model.

For all locations, the simulated experiment was conducted in a Rhodic Ferralsol, according to WRB soil classification, or Latossolo Vermelho Distrófico in Brazilian soil classification, EMBRAPA-SiBCS (Dalmolin et al., 2004).

The simulation was done aiming to obtain the maximum potential yield production for the crop, so aspects like soil water availability supplied by irrigation and fertility, were considered ideal by the crop model, relating only the photoperiod and weather conditions. The area space arrangement of length between rows and plants was not considered for this simulation, however, the CSM accept the plant distribution as population density, which was applied as 230 seeds per m^2.

The short period cultivar BRS Primavera was used to perform the simulations, once it is already calibrated and validated for applications in the crop model ORYZA2000. The experiment simulation was implemented in the mentioned locations, in 8 different dates at the summer planting season:Nov 1st, Nov 10th, Nov 20th, Dec 1st, Dec 10th, Dec 20th, Dec 30th and Jan 9th.

After processing the simulation by the model, output files were generated and formatted to be used for statistical programs. The 33 run simulations (years) for each location and planting date, were summarized in average values to better manipulate the obtained values and easier represent these data by graphs, maps and tables.

To build maps, aiming the better way to show the information collected for each location, were used shape files of Rondônia state, obtained in the web site database of Brazilian Institute of Geography and Statistics (IBGE). The shape files and data generated

by simulations were crossed using some tools founded in geostatistical packages acquired to a computer program called R.

RESULTS& DISCUSSION

Simulations for each sowing date has showed a correlation foraverage potential yield of all locations and delays in the crop establishment on the area. Rondônia is located in a transition area of morphoclimatic domains between Amazon Forest and Savannas, which is observed a seasonality of raining periods, with constant rains at the beginning of summer season for agriculture (October to March), occurring some episodes of dry season among the days of January and February (Klein, 2002).

Table 1. Average potential grain yield production for each studied location, in the state of Rondônia, on different plating dates.

	PGY (kg ha^{-1})							
Municipality	**Nov 1st**	**Nov 10th**	**Nov 20th**	**Dec 1st**	**Dec 10th**	**Dec 20th**	**Dec 30th**	**Jan 9th**
ARIQUEMES	4637.2	4486.1	4485.9	4497.2	4380.8	4408.8	4402.8	4392.2
CACOAL	4521.6	4415.2	4419.2	4397.9	4340.1	4256.0	4278.4	4228.8
GUAJARA-MIRIM	4449.2	4369.3	4356.6	4367.1	4308.5	4278.2	4300.6	4262.2
JI-PARANA	4488.0	4444.1	4377.2	4345.1	4273.8	4194.9	4242.9	4259.2
MACHADINHO D'OESTE	4498.1	4371.4	4342.6	4387.3	4286.4	4316.3	4316.1	4268.9
PORTO VELHO	4080.3	4057.8	4096.7	4042.2	4041.7	3950.4	3891.6	3848.9
VILHENA	5368.2	5302.5	5174.8	5021.6	4806.9	4698.3	4619.1	4629.9
Average	4577.4	4492.3	4464.7	4436.9	4348.3	4300.4	4293.0	4270.0
CV (%)	7.88%	7.91%	6.96%	6.13%	4.89%	4.87%	4.68%	5.04%

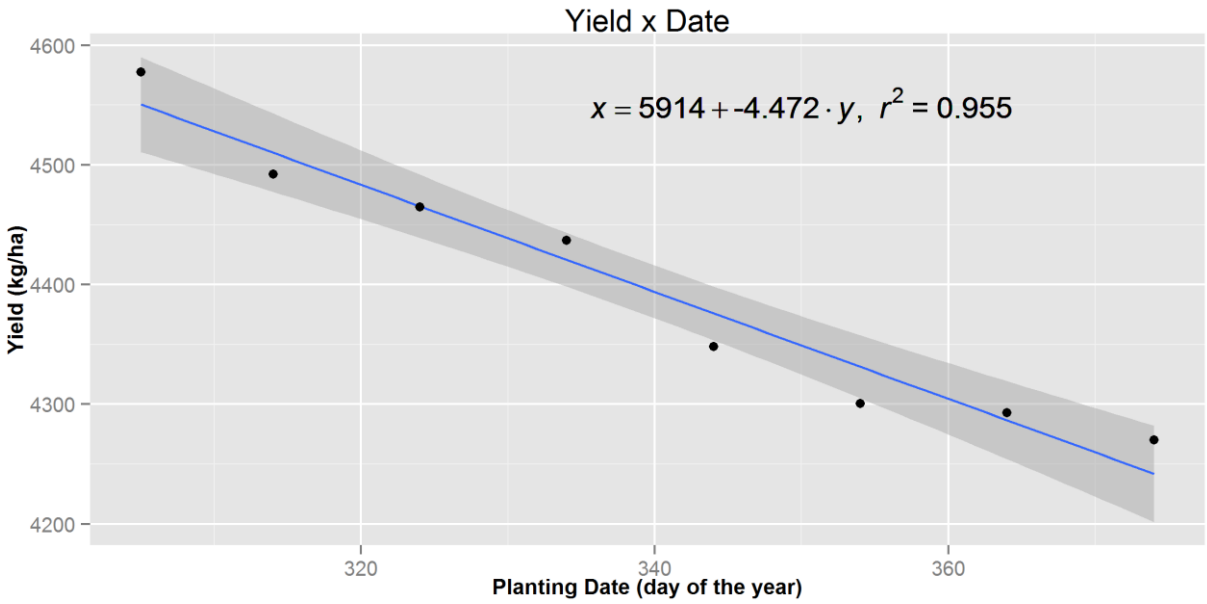

Figure 1. Regression line showing the correlation between the planting date and the effect in grain yield production.

Early sowing dates allows a better utilization of rains distribution in the plant cycle, having a good water availability in growing and maturation phases.

ULR is considered as a low yield crop, with estimated global average of 1,5 t ha^{-1} (Pandey et al., 2006b). However, in all simulations, the PGY results are superior compared to the global average, demonstrating the potential of this crop on this region.

During the all plant cycle, the average ETP ranged between 470.47 mm (Porto Velho) and 496.32 mm (Guajará-Mirim). For the state, the average ETP during the cycle was 584.8 mm $cycle^{-1}$. The highest average value was observed also in Guajará-Mirim for planting date of Nov 1st (497.96 mm) and the lowest in Vilhena for planting date of Jan 9th (471.84 mm).

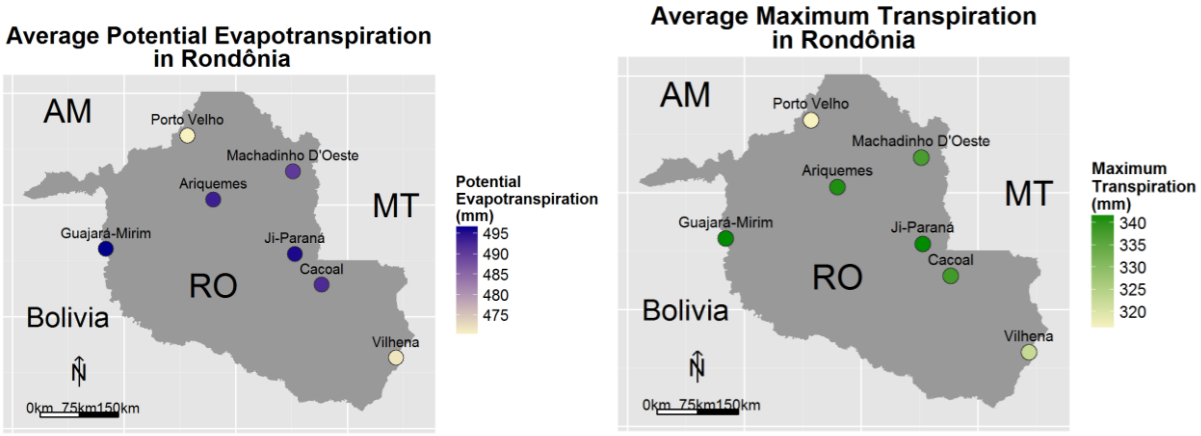

Figure 2. Maps showing the Average Potential Evapotranspiration (transpiration+evaporation, ETP)(left), and Maximum Transpiration (TRC)(right) at Rondônia during the simulated period, for each location.

The places which has shown the highest values for ETP, also represents the highest values for TRC, what proves the effect of elevated temperatures on those localities, by the occurrence of high demand in plant transpiratory activity (Pallas, 1967).

The ETP and TRC levels for each location also give an idea about the water availability in this specific region, once that most part of the evapotranspirated content, is provided by plant transpiration, presenting a condition of high temperatures and rainfall, considered as ideal for upland rice cultivation (De Datta, 1981).

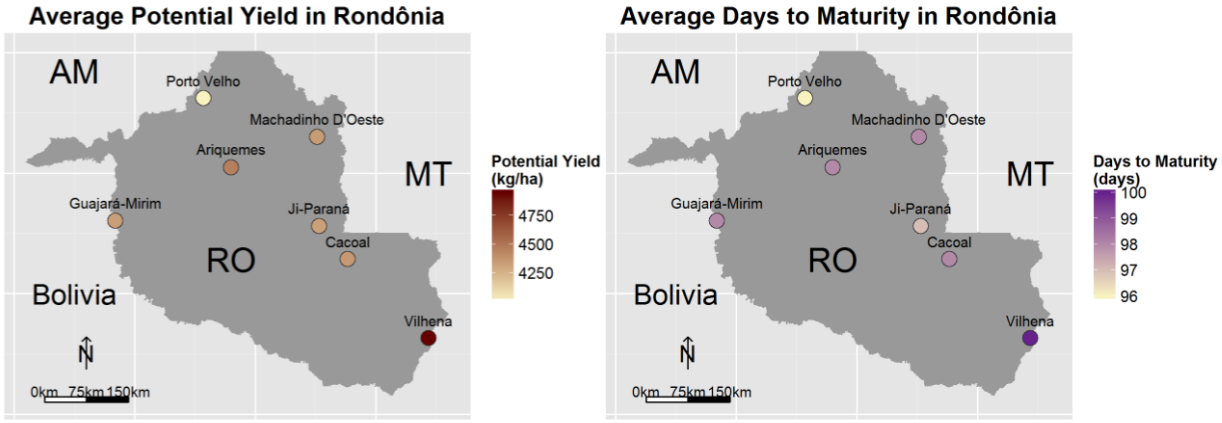

Figure 2. Maps showing the Average Potential Grain Yield (PGY)(left) and the period of days between sowing and plant maturity (right), at Rondônia during the simulated period, for each location.

Vilhena, has presented low values for ETP and moderated for TRC, but resulted as the highest PGY, at the planting date of Nov 1st (5368.2 kg/ha) and for the average values of all simulated dates (4952.67 kg/ha), followed by Ariquemes (4431.39 kg/ha). The lowest PGY was found in Porto Velho, at the planting date of Jan 9th (3848.9 kg/ha) and also the lowest average value of 4001.21 kg/ha.

As well as Vilhena, Porto Velho also had the minorsvalues of ETP and TRC, but the soil conditions and temperatures are the variables to be considered in this case. The maximum average temperatures cumulated during the cycle in Porto Velho (3072.33 ºC cycle^{-1}) is higher than what is founded in Vilhena (2948.96 ºC cycle^{-1}), and the same for minimum average temperatures cumulated (2169.41 ºC cycle-1 and 2019.00 ºC cycle-1, respectively).

Observing the locations with highest PGY's and longer cycle period of days to reach the maturity, is well noticed the effect crop duration in the final production. Variables like temperature and sun radiationhasa direct relation in the plant development (Vieira et al., 1999). As all locations are considerably close, the most probable variable affecting the duration of plant cycle is temperature. Porto Velho is a good example. This place has higher temperatures than Vilhena, presenting a faster cycle, therefore minor values of PGY.

CONCLUSION

Crop growth models are useful tools for decision making and information production to several subjects.

The municipality of Vilhena has showed the best results related to yield, compared to the other approached areas. That place is also among the lowest values of potential evapotranspiration and maximum transpiration, what justify the yield results in parallel with climate aspects, pointing the south of state as the best areas for upland rice production.

Also related with climatic aspects in the south of Rondônia, the temperatures affects directly the cycle duration, providing a longer period between sowing to maturity, which reflects in a higher production due a major photosynthesis time activity for grain production.

Delays of sowing dates is related to decreasing values of yield for all approached locations, due the well distribution of rains, temperature and sun radiation in the period initiated at the beginning of summer season crops.

In a overview, the actual production in Rondônia compared with the potential yield obtained by simulations, shows that there isn't enough investments and incentives to stimulate farmers to increase their productions, since that kind of crop management is well regarded for demanding markets because of minimal uses of water resources.

REFERENCES

BOUMAN, B. **ORYZA2000: modeling lowland rice**. IRRI, 2001. ISBN 9712201716.

BOUMAN, B.; VAN LAAR, H. Description and evaluation of the rice growth model ORYZA2000 under nitrogen-limited conditions. **Agricultural Systems,** v. 87, n. 3, p. 249-273, 2006. ISSN 0308-521X.

CONAB, Companhia Nacional de Abastecimento.**Acompanhamento de safra brasileira 2014**. Avaible from: <http://www.conab.gov.br/OlalaCMS/uploads/arquivos/14_10_23_10_20_02_boletim_graos_outubro_2014.pdf>. Acess on: May 10, 2015.

CONAB, Companhia Nacional de Abastecimento. **Séries históricas: Safras**. Avaible from: <http://www.conab.gov.br/OlalaCMS/uploads/arquivos/15_05_13_10_42_03_arrozseriehist.xls>. Acesson: May 10, 2015.

DALMOLIN, R. S. D, et al. Correspondência entre o Sistema Brasileiro de Classificação de Solos (Embrapa, 1999), WRB (Issswg Rb, 1998) e o Soil Taxonomy(USDA, 1999) para as principais unidades de solos do Rio Grande Do Sul.**Centro de Ciências Rurais-UFSM**, Santa Maria,v. 10, 2004. 4 p.

DE DATTA, S. K. **Principles and practices of rice production**. Int. RiceRes. Inst., 1981. ISBN 0471097608.

EMBRAPA. Centro Nacional de Pesquisa de Solos. **Sistema brasileiro de classificação de solos**. Brasília, DF: Embrapa Produção de Informação; Rio de Janeiro: Embrapa Solos, 1999. 412 p.

EMBRAPA. Informações técnicas sobre o arroz de terras altas: estados de Mato Grosso e Rondônia – safras 2010/2011 e 2011/2012. Empresa Brasileira de Pesquisa Agropecuária, 2012. 112 p.

FAOSTAT. FAOSTAT online database. Avaible from:<http://faostat3.fao.org/browse/Q/QC/E>. Acess on: May 10, 2015.

GUPTA, P. C.; O'TOOLE, J. C. **Upland rice: a global perspective**. Int. Rice Res. Inst., 1986. ISBN 9711041723.

HEINEMANN, A.; HOOGENBOOM, G.; DE FARIA, R. Determination of spatial water requirements at county and regional levels using crop models and GIS: An example for the State of Parana, Brazil. **AgriculturalWater Management,** v. 52, n. 3, p. 177-196, 2002. ISSN 0378-3774.

IBGE, Instituto Brasileiro de Geografia e Estatística: Downloads. Avaible from <http://downloads.ibge.gov.br/downloads_geociencias.htm>. Acess on: May 10, 2015.

JONES, J. W. et al. The DSSAT cropping system model. **European journal of agronomy,** v. 18, n. 3, p. 235-265, 2003. ISSN 1161-0301.

KLEIN, A. L. **Eugen Warming e o cerrado brasileiro: um século depois**. Unesp, 2000. ISBN 8571393540.

KREYE, C. et al. Possible causes of yield failure in tropical aerobic rice. **Field crops research,** v. 111, n. 3, p. 197-206, 2009. ISSN 0378-4290.

Ministério da Agricultura, Pecuária e Abastecimento. Plano Agrícola e Pecuário 2011-2012. Secretaria de Política Agrícola. – Brasília: Mapa/SPA, 2011. 92 p

PALLAS, J. E.; MICHEL, B. E.; HARRIS, D. G. Photosynthesis, transpiration, leaf temperature, and stomatal activity of cotton plants under varying water potentials. **Plant physiology,** v. 42, n. 1, p. 76-88, 1967. ISSN 0032-0889.

PANDEY, S. **Upland rice, household food security, and commercialization of upland agriculture in Vietnam**. Int. Rice Res. Inst., 2006. ISBN 9712202100.

TEAM, R. C. **R: A Language and Environment for Statistical Computing**. Vienna, Austria: R Foundation for Statistical Computing 2015.

VAN ITTERSUM, M.; DONATELLI, M. Modelling cropping systems—highlights of the symposium and preface to the special issues. **European Journal of Agronomy,** v. 18, n. 3, p. 187-197, 2003. ISSN 1161-0301.

VIEIRA, N. R. de A.; SANTOS, A. B. dos; SANT'ANA, E. P. (Ed.). **A cultura do arroz no Brasil**. Santo Antônio de Goiás: Embrapa Arroz e Feijão, 1999. p. 452-462.