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Can Brazil produce enough rice to meet demand in 2028?

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ABSTRACT

The objectives of the study were estimate the additional yield that may be achieved by reducing the yield gap in actual rice area, evaluate if irrigated rice production meet future demand for rice without increase area and determine sowing date that allows maximum yield potential. The yield gap (Yg) was determined by the difference between yield potential (Yp) and actual yield (Ya). The Ya was obtained from surveys applied to the rice producers. The Ya was 51% of Yp, and the Yg was 49%. In a scenario of high demand, if the yields follow the historical rate of gain, the production should not be sufficient to meet projected demand without 6% expansion of the currently cultivated area, whereas for a scenario of low demand it should be sufficient. Moreover, for the low and high demand scenarios, if the national average yield reaches 80% of the rice Yp, a reduction until 29% in the current irrigated rice area can occur. Sowing between September and mid-November is a way of making it possible to obtain yields close to 80% of Yp without increasing production costs. This study can be used as an aid in the search for world food security.

Keywords: Oryza sativa; Yield gap; Food security

1 INTRODUCTION

Food security and biodiversity conservation are important issues that are being discussed to assess decision-making in order to increase agricultural production through sustainable intensification (BURNEY et al. 2010; LAURANCE et al. 2014). Studies indicate that the world population will exceed nine billion by 2050 (UNITED NATIONS POPULATION FUND, 2018), and from this scenario, it is necessary to increase food production, quantity and quality, to meet the nutritional needs of the world population. An alternative to increase food production is to expand the agricultural area, but most of the available area presents high risk to agricultural activities and are in regions with wide biodiversity (KONING et al., 2009). Another

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alternative is to increase the production of crops vertically, by increasing yield, aiming to reach 80% of the yield potential (Yp) and reduce the yield gap (Yg), which is more indicated from a socio-environmental point of view (CASSMAN et al., 2003).

Yield potential is defined as the yield of an adapted cultivar, grown without limitations of water and nutrients, and without biotic or abiotic stresses (EVANS, 1993). Yp can be determined by crop models that consider the environment (solar radiation, temperature, concentration of atmospheric carbon dioxide) and the genotype (cultivars) (MARIN et al, 2016a). The actual yield (Ya) is determined from the average yield achieved by the farmers in each region, obtained through surveys, as proposed by the Global Yield Gap Atlas methodology (GLOBAL YIELD GAP ANALYSIS, 2019). The Yg is defined as the difference between Yp and Ya. The size of the gap indicates the additional production that can be achieved in a production area for a given cultivar and region (MARIN et al., 2016a).

Nowadays, Brazil is the world's largest rice producer outside the Asian continent, with an area of 1.6 million hectares and annual production of 10,4 million tons (COMPANHIA NACIONAL DO ABASTECIMENTO , 2019), which corresponds to 2% of world production. From 1980 to 2019, rice sown area in Brazil was reduced by 70%, replaced by higher commercial value activity, such as cultivation of soybean or cattle. Thus, the reduction occurred mainly in upland areas, where the rice is produced in rainfed systems, which currently represents 28% of the rice area and only 10% of rice production. Following this trend, there are projections that, in about ten years, rice will be grown only in lowlands in Brazil (MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO, 2017), which will increase the average yield of the crop, since rainfed rice is a high-risk crop with low yields and grain quality (SANTOS et al., 1995).

In the same way as the area, domestic rice consumption in Brazil has been declining annually, as the per capita income of the Brazilian population increases, and consumers spend less in starchy staple foods such as rice (COMPANHIA NACIONAL DO ABASTECIMENTO, 2018). This trend is not observed worldwide, as for less developed countries rice is still projected to be one of the main sources of food and world rice production is expected to increase by 40% during the next three decades

(WORLD METEOROLOGICAL ORGANIZATION, 2012). According to Van Ittersum et al. (2016), global cereal demand will increase 60% by 2050 compared to 2005/2007, and in the Sub-Saharan Africa this increase will be even higher, making it the region with the highest food security risk, and therefore with a greater need for agricultural products from other parts of the world. Even reaching 80% of the yield potential in all crops by 2050, Sub-Saharan Africa will not be able to supply the estimated demand for cereals (VAN ITTERSUM et al., 2016). Other studies showed that most countries in the African continent will not be self-sufficient in rice production until 2025 (VAN OORT et al., 2015).

In Brazil, studies for sugarcane showed that under a scenario of high demand for sugarcane, it will be necessary an expansion of 13% in the cultivated area or even a reduction of area for a low demand scenario, if the productivity reaches 80% of the yield potential (MARIN et al., 2016a). According to Strassburg et al. (2014), there are projections that Brazil can go through the largest increase in agricultural production in the next four decades. Thus, Brazil may be responsible for meeting the demand of other countries that are not self-sufficient in the food production, especially in rice. In this regard, rice yield gaps were estimated in two demand scenarios for domestic consumption in Brazil in 2028, to analyze how much of the rice production will exceed the domestic consumption, being able to be exported. In scenario 1, rice production was estimated by historical yield increase rate. In scenario 2, rice production reached 80% of the yield potential, according to a methodology proposed by Cassman et al. (2003) and Marin et al. (2016a). The objectives of the study were (a) estimate the additional yield that may be achieved by reducing the yield gap in actual rice area, (b) evaluate if irrigated rice production in 2028 may meet future demand for rice without increase area and (c) determine sowing date that allows maximum irrigated rice yield potential in Rio Grande do Sul.

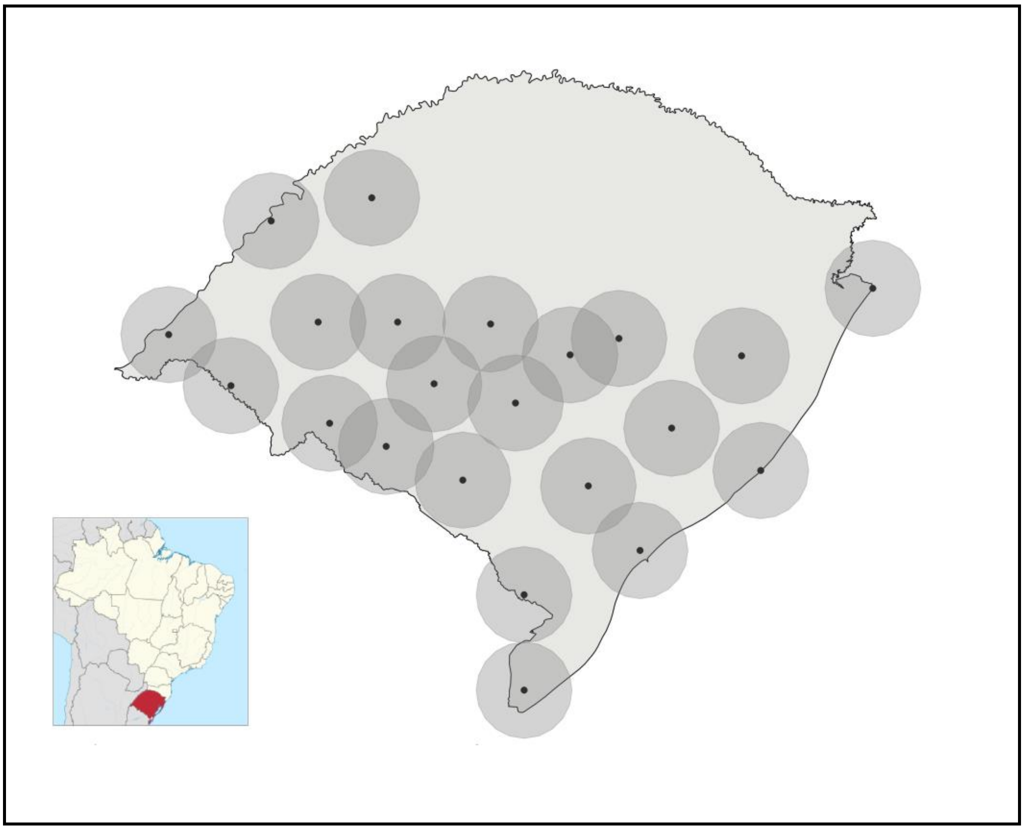
2. MATERIAL AND METHODS

2.1 Data used to determine yield potential, average yield and yield gap

In this study, the yield that maximize farmers' profit was settled as 80% of Yp, following the methodology proposed by Cassman et al. (2003) and Marin et al. (2016a). Rice yield potential was estimated at 15 Mg ha^{-1} (GLOBAL YIELD GAP ANALYSIS, 2019). Actual yield was obtained from field surveys applied for rice farmers in Rio Grande do Sul during the last five growing seasons (2014/2015, 2015/2016, 2016/2017, 2017/2018 and 2018/2019). These surveys were performed by the Rio Grandense Rice Institute (IRGA), Federal University of Santa Maria (UFSM) and Federal University of Pampa (UNIPAMPA).

Yield gap was determined by the difference between Yp and Ya, indicating how much yield is possible to increase in a field and/or region. The Yp and yield gap were estimated for flooded rice, since 90% of Brazilian rice production is under this system, mainly in Rio Grande do Sul State (RS), which is responsible for 71% of national production (MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO, 2020). Harvested rice area in RS was obtained from agricultural data of three growing seasons (2016, 2017 and 2018), within a 50 kilometer radius of each automatic weather station (22 weather stations in total) from National Institute of Meteorology (INMET) (Figure 1) (Marin et al., 2016a). The harvested area covered by the stations in RS during these three growing seasons represented more than 50% of harvested rice area in Brazil (COMPANHIA NACIONAL DO ABASTECIMENTO , 2018), following the methodology proposed by Van Wart et al. (2013), thus providing a robust national scale estimate to assess yield gaps.

Figure 1 – 50 km radius surrounding the 22 meteorological stations distributed in Rio Grande do Sul



Source: Instituto Rio Grandense do Arroz (IRGA) and National Institute of Meteorology (INMET)

2.2 Evaluation of future scenarios for area and production of irrigated rice in Brazil

Fo rice demand evaluation in future scenarios, two scenarios were considered: 1) SAO PAULO INDUSTRY FEDERATION (FIESP) (2018) in which domestic rice demand will be 13 Mt by 2028; and 2) MINISTRY OF AGRICULTURE, LIVESTOCK AND SUPPLY (MAPA) (2018) in which domestic rice demand will be 12,2 Mt, showing a relative stabilization of rice consumption projected for 2028. FIESP projection is based on an input-output model that assesses the global balance of food production and consumption, in which the demand of each country was established based on food income elasticity and expected rates of economic growth. MAPA projection considers a bibliographical review of Brazilian and international organizations studies, some of them based on projection models, which evaluated future demographic data and economic growth.

FIESP's (2018) projected demand for rice consumption for 2028 was identified as high production demand (HD), while MAPA's (2018) projection was called low production demand (LD). The rice area required to meet LD and HD projections were estimated in two rice production scenarios: S1) The projected yield will follow the historical rate of yield gain from 1980 to 2018; and S2) Projected production will reach 80% of Yp in 2028, keeping the current production area. 80% of Yp was assumed as the maximum limit of economic achievable yield, and values higher than this become economically unfeasible in commercial farms, since it would be necessary to eliminate all abiotic and biotic stresses, which is difficult to achieve (CASSMAN et al., 2003; KONING, 2009).

Scenarios were evaluated using irrigated rice harvested area in southern Brazil (COMPANHIA NACIONAL DO ABASTECIMENTO, 2015) and irrigated rice productivity in Rio Grande do Sul for the five last growing seasons. The historical yield rate used for S1 was estimated for the 38-year period (1980-2018) based on available statistics (INSTITUTO RIO GRANDENSE DO ARROZ, 2019). For S2 was used the Yp for Brazil, it was estimated of 15 Mg ha^{-1} (GLOBAL YIELD GAP ANALYSIS, 2019). The Yg was calculated as the difference between the average Yp and the average Ya of the last five years (2015-2019). This period was selected to avoid the technological trend that limits long-term use (MARIN et al., 2016a).

2.3 Checking the impact of sowing date on rice yield production

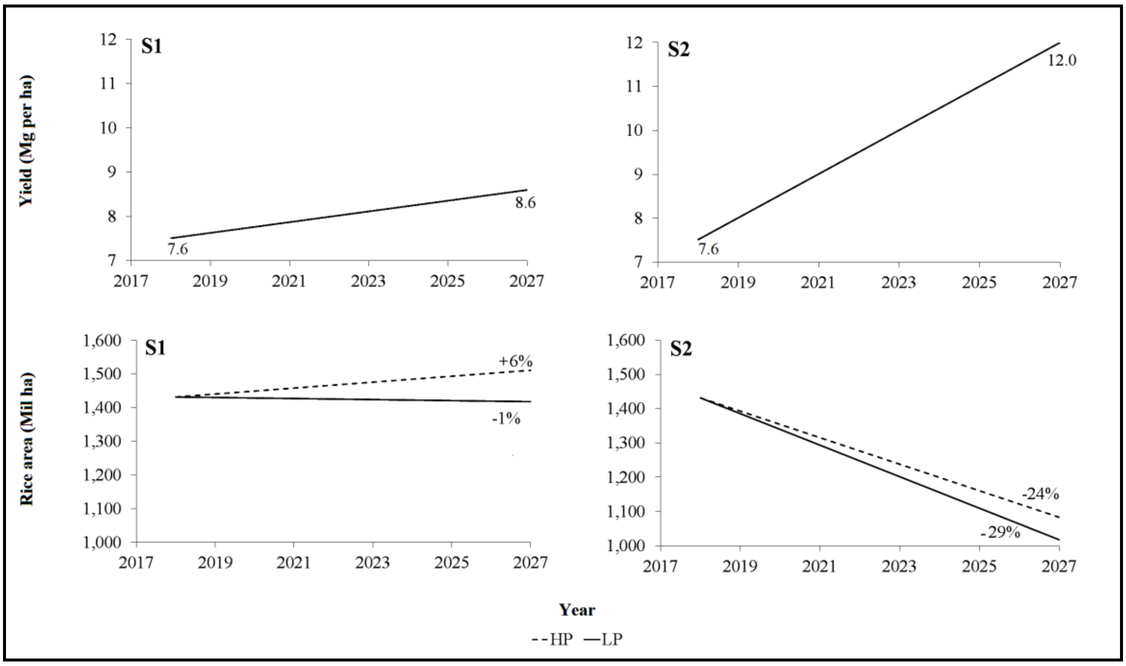
In this case, SimulArroz model was used to estimate yield potential, a process-based ecophysiological model tested and calibrated to simulate growth, development and yield of irrigated rice cultivars in flooded systems (STRECK et al., 2013; ROSA et al., 2015; RIBAS, 2016). The Yp was simulated separately for each of the 22 weather stations chosen, from 1981 to 2017, for each 1st and 15th of September, October, November and December, using the cultivar IRGA 424 RI, which represented approximately 50% of the area sown in the last growing seasons in Brazil (INSTITUTO RIO GRANDENSE DO ARROZ , 2019). Subsequently, average Yp of weather stations per sowing season were calculated. Thus, the Yp of irrigated rice in Brazil was obtained for sowing date.

3. RESULTS AND DISCUSSION

Currently, the actual yield of irrigated rice has reached 51% of the Yp, which was estimated in 15 Mg ha^{-1} (GLOBAL YIELD GAP ANALYSIS, 2019). This Yp is superior to Bangladesh Yp (11.7 Mg ha^{-1}) reported by Timsina et al. (2016). Thus, Yg for Bangladesh varies from 45 to 61% (TIMSINA et al., 2016) whereas in Brazil Yg is 49%. The yield potential of irrigated rice is high in southern Brazil because this region receives abundant solar energy daily average during a growing season (21 MJ m^{-2} day^{-1}, for September to March), which is equal or higher than all existing barns (regions that have a stable surplus production of one or more crops and have the ability to, in addition to meeting local demand, contribute to food supplies in other regions) in the world (CASSMAN, 1999). In this sense, southern Brazil has the potential to become a world granary in irrigated rice production.

Considering S1, in which the yield will increase 98 kg ha^{-1} $year^{-1}$, the rice production will not be enough to meet the consumption of Brazilian population in scenario HD by 2028, being necessary increase the farmable area by 6%. In LD scenario, the volume produced will be enough to meet the Brazilian population demand, thus it will be possible to reduce the area by 1% (Figure 2). In this sense, S1 indicates an average yield of 8.6 Mg ha^{-1} in 2028, representing an increase of 1.0 Mg ha^{-1} from 2018 to 2028, whereas Ya is 7.6 Mg ha^{-1}. The increase in yield at a rate of 98 kg ha^{-1} $year^{-1}$ is lower than that found in previous decades, where the yield of irrigated rice increased more expressively, however, the yield gain rate decreases over time after reaching yield plateaus (GRASSINI et al., 2013), achieved during the last decade in Brazil.

Figure 2 - Options to meet the high and low rice demand scenarios (HD and LD respectively) until 2028: changing yield (Mg ha^{-1}) (upper panels) or changing irrigated rice area (thousand ha) , for two scenarios: yield increase following the historical yield gain (S1, left panels) and yield reached by closing the exploitable yield gap - 80% of Yp (S2, right panels)



Source: authors

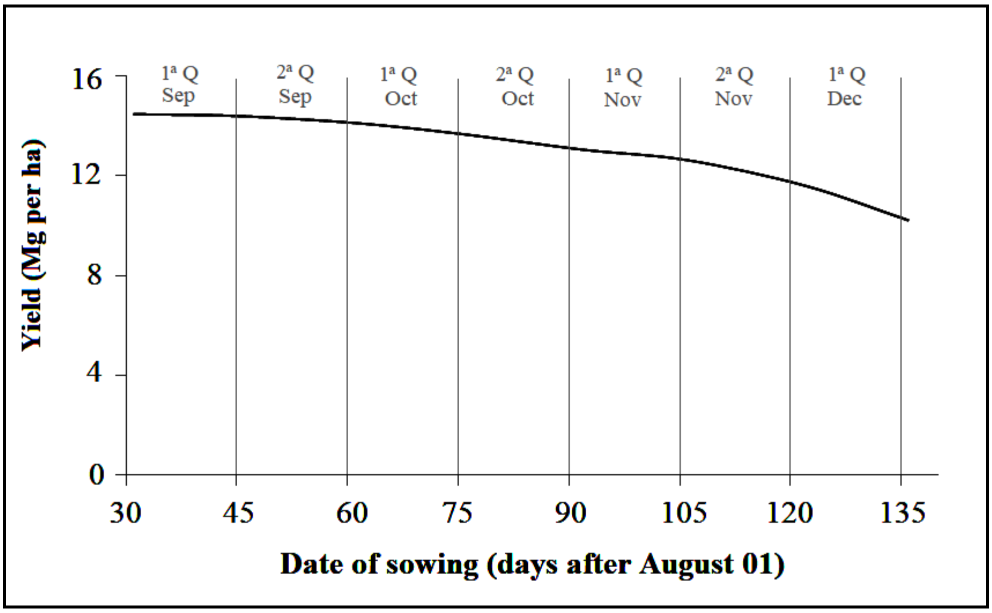
For S2, average yield will reach 12 Mg ha^{-1} in 2028, considering 80% of the exploitable Yp. In this scenario we assume that irrigated rice fields will increase the efficiency of resource use and use process-based management practices, increasing yield by 29%, as currently the average yield of irrigated rice in Brazil represents 51% of Yp. Reaching this yield, HD and LD will be met, and Brazil may reduce the planted area by 24 and 29%, respectively, or there will be a rice surplus corresponding to 4.1 and 4.9 million tons, respectively, by 2028. Just as Brazil, if Bangladesh achieves 80% of Yp by 2030, it will be self-sufficient in rice production, and may reduce its planted area by up to 10% (TIMSINA et al., 2016). So, Brazilian rice production will be able to supply part of the new global demand for rice, that is, part of the need for a 40% increase in world rice production in the next three decades (WORLD METEOROLOGICAL ORGANIZATION, 2012). Since the results suggest that Brazil has the potential to supply domestic demand and produce significant surplus for export. Considering that world rice production is 475 million tons (USDA/FAS, 2015), for HP the surplus production in 2028 would be responsible for supplying 2.2% of the need for increased production in the next three, while LP would supply 2.6% of this demand. In this sense, decision makers in the Brazilian agribusiness sector should seek for alternatives to improve the market for import and export rice, in order to prevent the rural exodus from continuing to increase, given that Brazil is able to supply its consumption demand by 2028, with the possibility of having a large surplus. This issue is of great socioeconomic importance, since the possible reduction of area is quite expressive, and it is necessary to think about market strategies for this production, since many lowland areas where irrigated rice is grown are unfit for other uses.

Whereas the planted area is not altered, the Brazilian production surplus, for the S1 will be 0.1 Mg ha^{-1}, with a low cereal demand and for S2, in high or low demand, the surplus will be 2,9 or 3,5 Mg ha^{-1}, respectively. If per capita rice consumption by 2028 in developing countries, such as Brazil, is approximately 55 kg inhabitant^{-1} year^{-1} (FEDERAÇÃO DAS INDÚSTRIAS DO ESTADO DE SÃO PAULO, 2017), this surplus can feed, respectively, 20.9, 76.0 or 90.6 million people for year. There are projections that by 2026 the population of the African Continent will be 1.5 billion people (COMMISSION ÉCONOMIQUE DES NATIONS UNIES POUR L'AFRIQUE, 2016), so the surplus of Brazilian rice production will be able to supply 0.6% of the per capita consumption of rice in Africa in S1, and 3.6 or 6% in the S2, according to the consumption demand of rice of the Brazilian population (HD or LD). This is of fundamental importance, since, according to Van Ittersum et al. (2016), Sub-Saharan Africa is currently the world region with the greatest discrepancy between consumption and production of cereals, and, thus, depends substantially on imports to meet domestic demand. In addition, it is the region with the highest projections of increased consumption between 2016 and 2050, so to maintain the current perspective of the cereal self-sufficiency level in 2050 (i.e. 80%), it will be necessary to increase the yields by reaching 100% of the yield potential of cereals. In other words, Sub-Saharan Africa will not be able to be self-sufficient in cereal production even when Yg is zero, without increasing production area (VAN ITTERSUM et al., 2016).

3.1 How to reach 80% of the Yp?

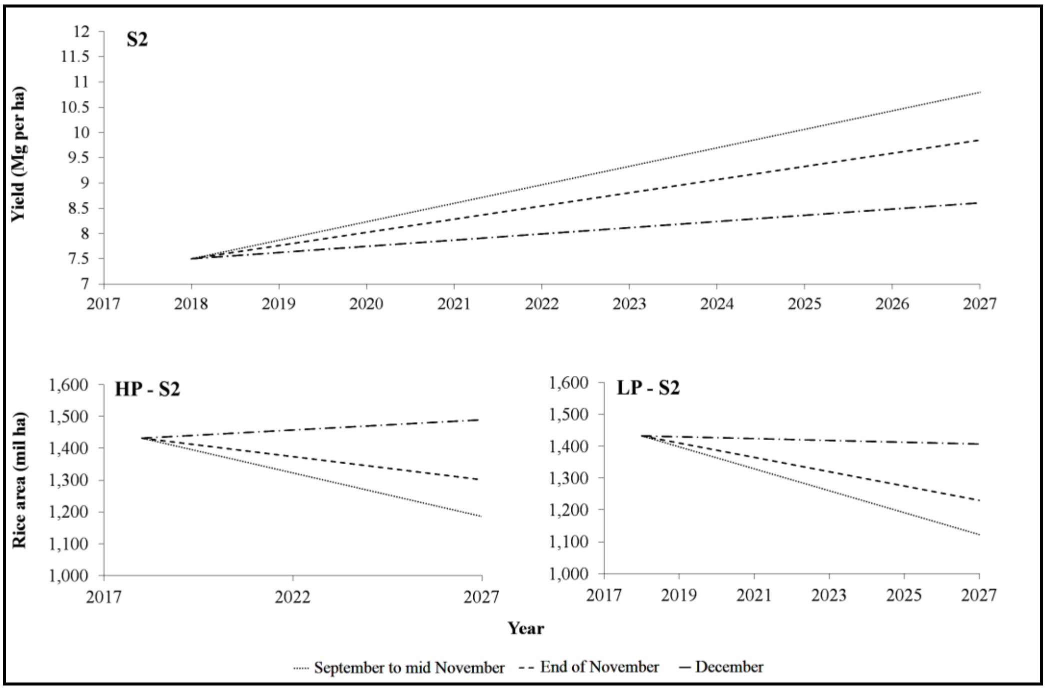
One of the limiting factors to obtain 80% of rice Yp in Rio Grande do Sul is late sowing, since this factor leads to a significant reduction of Yp (Figure 3). In order to reach 80% of Yp without increasing production costs (SLATON, 2003), it is necessary to match the reproductive period with the high availability of solar radiation and suitable temperatures for the crop (FREITAS et al., 2008), and for this, the sowing in Rio Grande do Sul should occur from September to mid-November (Figure 4). This leads to a higher yield and it is possible to significantly reduce the cultivated area for both demand scenarios. Or even, it implies in greater production without altering the area of cultivation, allowing to increase the rice exportation in the current area. The results of this study show that it is possible to supply the Brazilian demand for rice, with a vertically increase in grain production, i.e., by intensification of production (BURNEY, 2010), producing only in areas that are currently occupied by the crop in the irrigated system, even reducing the area if 80% of Yp is reached.

Figure 3 - Potential yield of irrigated rice as a function of sowing date in the state of Rio Grande do Sul for cultivar IRGA 424 RI, using meteorological data from 1980 to 2017 and SimulArroz model to estimate a potential condition



Source: authors

FIgure 4 - Yield (Mg ha-1) reaching the exploitable yield gap - 80% of Yp (S2); and area (thousand ha) required to meet the high demand (HD) and low demand (LD) scenarios, according to the sowing date for cultivar IRGA 424 RI, using meteorological data from 1980 to 2017 and SimulArroz model to estimate a potential condition.



Source: authors

Projections made by the Food and Agriculture Organization (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2014) point to an increase of the world's population of approximately 30% by 2050, and it is necessary to increase agricultural production by 60% to meet the demand for food. Thus, Brazil, which is already a major global food supplier (MARIN et al., 2016b), will become even more prominent in the global food security search scenario.

4. COMCLUSIONS

The yield gap of irrigated rice in Brazil is 49%, and the yield of the crop can increase by 4.4 Mg ha^{-1} until 2028, if 80% of the yield potential is achieved.

The country has the potential to meet future demand in all situations evaluated, except for a scenario in which high consumption demand occurs and yield increases following the historical rate. For S1, high production demand cultivated area should increase by 6% to meet consumer demand. Already for LP the cultivated area can reduce 1%. In S2, area can be reduced by 24 and 29%, respectively for high production demand and low production demand, that the demand will still be supplied.

In Rio Grande do Sul, irrigated rice should be sown until mid-November, allowing maximum expression of its yield potential.

The results of this study can be an aid to the definition of public policies regarding the commercialization of rice, associated with environmental issues and guarantee of world food security.

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