YIELD GAP ANALYSIS OF IRRIGATED RICE IN URUGUAY AND COMPARISON WITH OTHER RICE PRODUCING COUNTRIES

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INTRODUCTION

The Uruguayan rice sector has been one of the most successful and most integrated agricultural industries in the country. Rice yields in Uruguay have increased at one of the highest annual rates worldwide (145kg^{-1} ha^{-1} yr^{-1} from 2000 to 2017). However, this trend has shown a marked slowdown in recent years, which may be indicating that average rice yields approach the biophysical yield ceiling (Figure 1). Indeed average farm yields often begin to plateau when they reach 75 to 85% of the yield potential (CASSMAN et al., 2003; LOBELL et al., 2009). Determination of rice yield potential in Uruguay, is essential to identify opportunities for future yield gains. Also unknown is if the high increase in rice yield in Uruguay was partially determined or not by climate change. Due to current high inputs costs and low rice prices, keeping rice yields trend is critical for the viability and sustainability of the crop in Uruguay. The aims of this work were: firstly, to estimate rice yield potential (Yp) and current exploitable yield gaps (Yg) at regional and local-farm levels in Uruguay, secondly, to analyze current rice yield trends in Uruguay and to determine to which degree the incipient yield plateau can be attributed to a biophysical limit and thirdly to compare results with other rice producing countries included in the Global Yield Gap Atlas for which rice yield potential and yield gap estimates are available.

MATERIAL AND METHODS

Methodology and protocols developed by the Global Yield Gap Atlas (GYGA, www.yieldgap.org) were followed in order to select data sources, define the agro-climatic zones in Uruguay, simulate crop yield, and estimate yield gaps at local to national levels (VAN WART et al., 2013a, 2013b; VAN BUSSEL et al., 2015; GRASSINI et al., 2015). Data on current farm yields (Ya) were collected from the Uruguayan rice industry database. The crop simulation model Oryza V3 was used to simulate Yp over a period of 18 years for each of the 7 selected reference weather stations (RWS). Yg was determined as the difference between 80% of Yp and average Ya over the past five years weighted by the cultivated rice area. Two independent datasets were used for model calibration and validation. Comparison of simulated flowering and maturity dates against measured data from experiments and yield validation, indicated good agreement between simulated and observed values giving confidence in model performance for rice in Uruguay.

RESULTS AND DISCUSSION

Rice yields in Uruguay have increased at 176 kg^{-1} ha^{-1} yr^{-1} from 2000 to 2010, while a non significant yield increase was registered from 2011 to 2017 (Figure 1). Average estimated rice yield potential Yp in Uruguay, for a period of 18 years weighed by planted area in seven weather stations was 14 t ha^{-1} (Figure 2).

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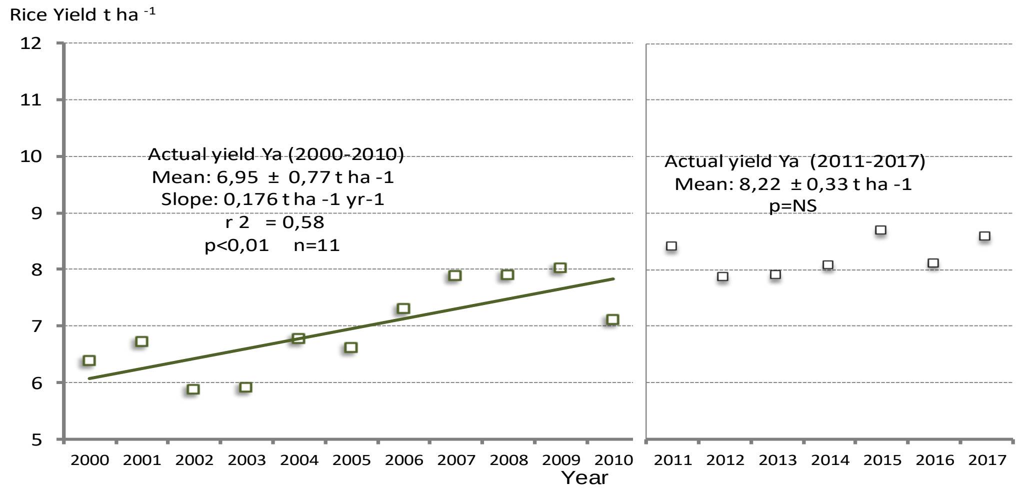

Figure 1. Actual rice yield trend average registered in Uruguay during two periods: I. from 2000 to 2010 II: from 2011 to 2017. Source DIEA MGAP.

The lack of trend in the average yield potential in Uruguay registered during this period is indicating that there was no significant effect of climate change on the rate of increase of rice yields in Uruguay. Rice chain integration, research transfer and adoption of new crop management technologies, allowed to achieve high rates of yield increase over the past years (145 kg ha^{-1} year^{-1} from 2000 to 2017) (Figure 2). Some of the major technological changes were the release of high yielding varieties, crop planted at the optimum date, improved soil management practices, high response to N fertilization, less disease problems, early weed control, early flooded irrigation, use of certified seed and rotation with pastures for grazing cattle.

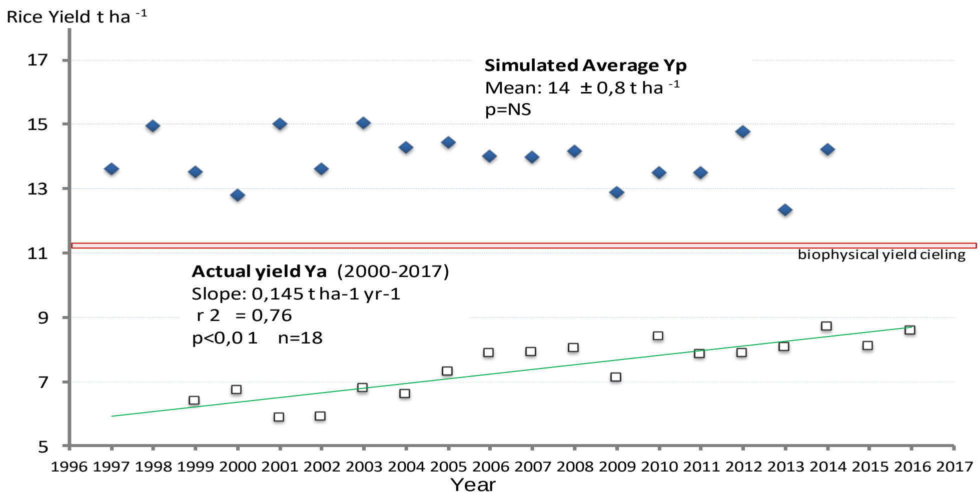

Figure 2. Simulated rice yield potential Yp for Uruguay with OryzaV3 (diamond) average of 7 reference weather stations (RWS) from 1997 to 2014 and actual Ya rice yield trend (square) Source DIEA MGAP. Linear regression slope for Yp was close to zero.

Even when Uruguay has exhibited a high yield gain rate for irrigated rice and one of the highest Ya, our work suggested that actual rice yields have not reached yet 80% of the yield potential ceiling in Uruguay (Figure2). Given an average Yp of 14 t ha^{-1} (range of 13.0-14.7 t ha^{-1}) cross rice-growing regions) and an Ya of 8 t ha^{-1} ranging from 7.7-8.5 t ha^{-1}, current exploitable yield gap is 3 t ha^{-1} (ranging from 1.9 to 4.1 t ha^{-1}) (Figure 3). Hence average relative yield of Uruguay represents 57% of simulated Yp at national level (Table 1).

This study showed that there were some differences in Yp, Ya achieved by farmers were very similar across regions and Yg was higher in Central and Southeast of Uruguay (Figure 3). Hence, there is an opportunity to target those areas to facilitate technological transfer. More research should be conducted to better understand differences in Yp among regions and about technical approaches to reduce expoitalbe yield gaps.

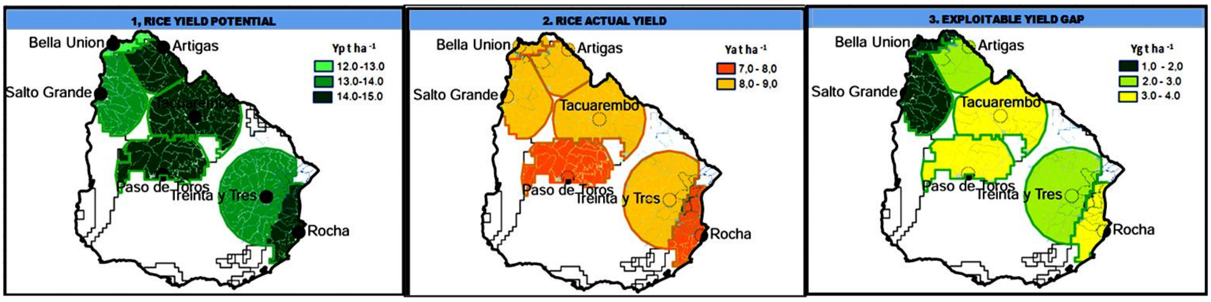

Figure 3. (1) Yield Potential (Yp), (2) Actual Yield (Ya) and (3) Exploitable Yield gap (Yg) by reference weather stations (RWS) in Uruguay.

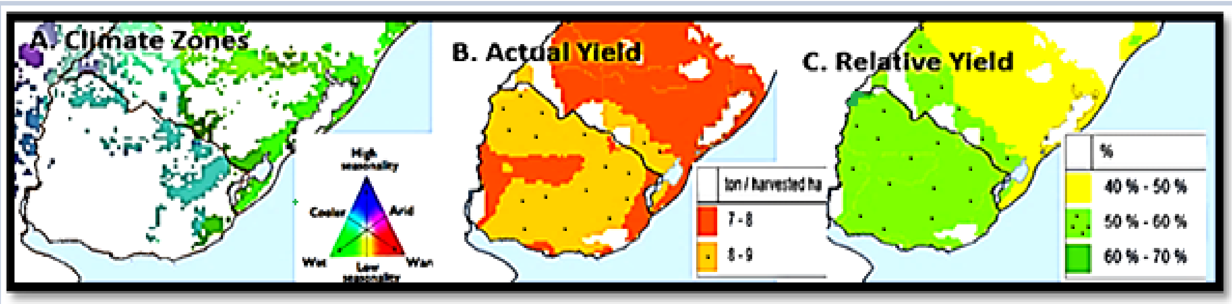

Figure 4. A. Climate zones (CZ) B. Actual yield by CZ and C. Relative yield by CZ for irrigated rice in Latin american countries (South of Brazil, Uruguay) included in the GYGA.

Table 1. Comparison of relative yield (%), Actual yield (Ya), Yield potential (Yp) and exploitable yield gap (Yg) for irrigated rice in different countries included in the Global Yield Gap Atlas. Source: GYGA. www.yieldgap.org .

Country	Relative yield (%)	Rice Yield (t ha $^{-1}$)		
		Potential (Yp)	Actual (Ya)	Exploitable Yield Gap (Yg)
USA	66	12.4	8.1	1.8
Uruguay	**57**	**14.0**	**8.1**	**3.1**
Brazil	51	14.8	7.6	4.3
China	68	9.5	6.5	1.1
Indonesia	63	9.5	6.0	1.6
Iran	59	7.3	4.4	1.5
India	49	9.0	4.4	2.8
Bangladesh	47	12.0	5.6	4.0
Egypt	81	11.9	9.6	0.0
Senegal	79	7.5	5.9	0.1
Rwanda	49	10.7	5.2	3.4
Niger	47	9.2	4.4	3.0
Mali	45	9.1	4.1	3.2
Tanzania	42	10.8	4.5	4.1
Burkina Faso	36	7.6	2.8	3.3
Ghana	33	8.3	2.7	3.9
Nigeria	32	8.9	2.8	4.3
Madagascar	24	10.3	2.4	5.8
Average:	**52**	**10.2**	**5.3**	**2.9**

Yield potential also varies across rice producing countries included in the Global Yield Gap Atlas, which is explained mainly by the wide range of environments where rice is grown and differences in cropping systems (Table 1). Amongst these countries, Brazil and Uruguay exhibits one of the highest yield potential, 14,8 and 14,0 t ha^{-1} respectively, but Ya and relative yield % are lower in

Brazil determining a higher Yg in this country (Figure 4). Average relative yield production for most countries, suggests it is still possible to increase grain yields within existing rice production areas, in order to contribute to meet the growing demand for food worldwide. Reducing yield gaps would improve rice farmers-industry economy result while producing more food. Sustainable intensification pathways that improve crop production while balancing, maintaining good environmental and sustainability indicators should be the priority and final goal. Rice producers from other countries, could consider the yield gains achieved in Uruguay as feasible targets and take advantage of local experience on rice farming systems and rice chain integration that allowed to achieve a very high rate of yield increase over the past years.

CONCLUSION

Current yield levels in Uruguay (8 t ha^{-1}) represent 57% of estimated yield potential (14 t ha^{-1}), indicating that it would be possible to further increase actual yields while reducing exploitable yield gaps in Uruguay.

The high rate of rice yields increase in Uruguay (145 kg ha^{-1} $year^{-1}$ from 2000-2017), was explained mainly by technological adoption, incorporation of new varieties and implementation of integrated crop management practices.

Average relative yield production for most countries included in the world atlas is still below 60%, indicating that it would be possible to increase rice yields within current rice planted areas, as they haven´t reached yet the biophysical ceiling.

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