THE CHANGING PATTERNS IN LAND ALLOCATION TO SOYBEANS AND MAIZE IN ARGENTINA AND THE AMERICAS AND THE ROLE OF GM VARIETIES. A COMPARATIVE ANALYSIS

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Abstract

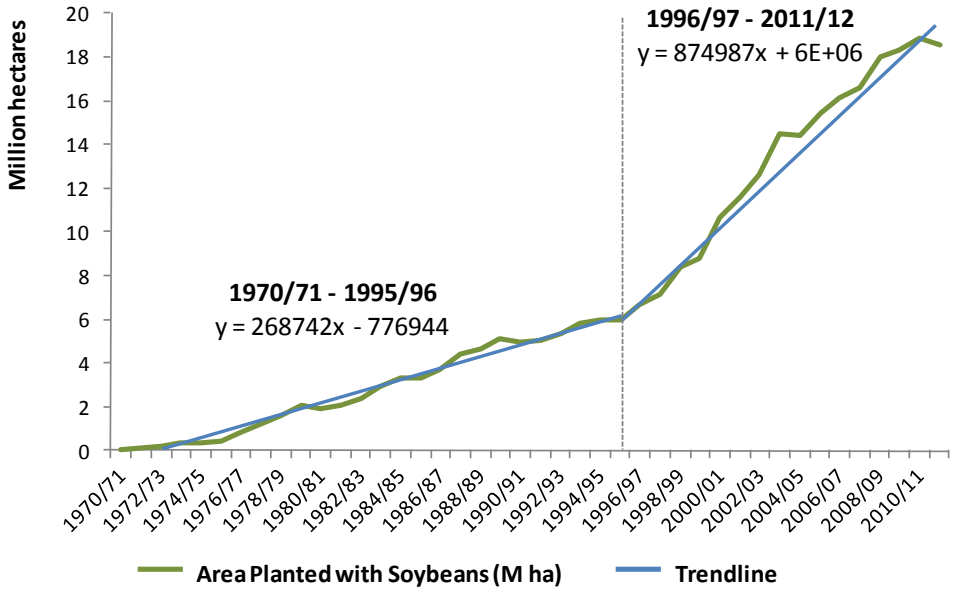
During the last fifteen years, the impressive increase in the area planted with soybeans in Argentina, since the commercial release of glyphosate-tolerant varieties in 1996, has sparked a heated debate about its implications. There is wide concern about the detrimental effects of this process, especially on organic matter content (its main competitor for land, maize, provides a significant amount of organic matter, which is not the case with soybeans).

A comparative analysis of the evolution of the area planted with both soybeans and maize was made between five countries in the Americas: The United States, Argentina, Brazil, Paraguay and Bolivia, for the crop seasons 1980/81 through 2011/12. An index was constructed to reflect deviations from an assumed equilibrium allocation of land, based on the ratio: area with soybeans / (area with soybeans + area with maize). This "relative land allocation index" (RLAI) was calculated for the countries included in the study for the period under analysis and the resulting trend lines were compared. Argentina was the country with the highest RLAI in 2011/12, with a deviation of 67% above the assumed equilibrium value for the RLAI (1.0), followed by Paraguay (that was already in "disequilibrium" at the beginning of the period of analysis), Bolivia and Brazil. The RLAI for the USA remained very close to the assumed equilibrium point for the entire period. Bolivia showed the highest positive rate for the RLAI series trend line (5%/yr), followed by Argentina (3%) and Brazil (2%). Both USA and Paraguay show a flat trend line (0%) but the casual factors are considered to be of a completely different nature. To estimate the effect of the commercial release of genetically modified (GM) glyphosate-tolerant soybeans on the RLAI, a simple linear regression model was constructed, using a dummy variable to control for the year in which glyphosate-tolerant varieties were made available to farmers. This variable turned out to be significant for Brazil, Argentina and Paraguay. The adjusted R^2 for Brazil resulted to be the highest (0.8), followed by Bolivia (0.6) and Argentina (0.5), suggesting that the availability of GM soybeans played a bigger role in the expansion of this crop in Brazil than it did in both Bolivia and Argentina.

1. Introduction

In 2003, a new word was coined by the then Secretary of Agriculture of Argentina: "sojización" (which could be translated into English as "soyafication" or "too much soybeans"). This term has not been defined with any degree of accuracy, besides the obvious: the current area planted with soybeans is assumed to be well above the optimum level from the perspective of the long-term sustainability of cropping systems.

Figure 1. *ARGENTINA: the evolution of the area planted with soybeans (1970/71-2011/12)*



Source: The authors based on data from MAGyP[1] (2012).

In a document published by the then Secretariat of Agriculture, Livestock, Fisheries and Food [2] (SAGPyA, for its Spanish acronym), the onset of this surprisingly fast expansion process is assumed to have a strong correlation with the commercial release of the glyphosate-tolerant genetically modified (GM) varieties. As can be seen in Figure 1, the trend lines for the 1970/71-1995/96 period and the 1996/97-2011/12 are clearly different (the expansion rate actually increased three-fold from the pre-1996 values, going from 269 to 875 thousand hectares per year). Galafassi[3] challenges this interpretation, stating that the disequilibrium started earlier and thus cannot be attributed solely to the availability of GM varieties, but he does not offer a criterion that would be of any assistance in identifying the point in the time-series that marks the beginning of the process by which the area with soybeans drifts away from what it is assumed to constitute a long-term sustainable level. Ciani[4] defines "soyafication" as a

[1] Ministry of Agriculture, Livestock and Fisheries (MAGyP for its Spanish acronym). Data available online at: http://www.siia.gov.ar/index.php/series-por-tema/agricultura

[2] Secretaría de Agricultura, Ganadería, Pesca y Alimentos (SAGPyA, 2002). The Secretariat was given ministerial level in 2007 and changed its name to Ministry of Agriculture, Livestock and Fisheries (MAGyP for its Spanish acronym).

[3] Galafassi, G. (2004).

[4] Ciani, R.; Esposito, A. (2005).

continuous process of growth of both production and domestic processing of soybeans, at the expense of other agricultural activities, which does not shed too much light on the subject either. It is likely that there could be yet other equally valid readings about the magnitude (absolute as well as relative) of the area planted with this crop that can be considered as a threat to the sustainability of the cropping systems of Argentina as we know them nowadays. In this paper we intent to address this issue, expanding the geographical area under analysis to include all major soybean growing countries in the Americas, allowing for comparisons between them.

Objectives:

1. To compare the status of "soyafication" in the Americas.
2. To evaluate whether the commercial release of GM materials has played a role in those countries where that process has actually been observed.

2. Methodology

We consider it necessary to propose a working definition of "soyafication", to provide a benchmark for the subsequent analysis.

Soyafication: it is a disequilibrium in the allocation of land, characterized by the predominance, sustained over a period of time, of soybeans over maize[5] that cannot be explained by changes in relative prices.

To agree on a definition is a necessary but not a sufficient condition to make comparisons between countries. To that purpose, a quantitative indicator is also required. The one proposed here is a very simple statistic that could be helpful in revealing the diversity of technological and productive arrangements of the cropping patterns of the countries under analysis.

2.1 The Relative Land Allocation Index (RLAI)

Definition of RLAI = [Area with soybeans/ (Area with soybeans + Area with maize)] x 2

An assumption is made in connection with the RLAI: if relative prices for these two commodities remain constant at a ratio such that net returns are not significantly different, then the equilibrium RLAI takes on the value 1.0 (that is, the areas planted both with soybeans and maize are equal). This is based on empirical facts:

1. The arable land areas with aptitude for these two crops have a high degree of overlapping, hence they can be considered as almost "perfect"[6] substitutes when competing for land.
2. The rotations schemes suggested by specialists (without contemplating crops-livestock options), for the southern region of the Province of Córdoba (Argentina), are the following[7]:

    2.1 Maize-soybeans-wheat/soybeans (double-cropping).

    2.2 Maize-wheat/soybeans (double cropping).

[5] These two crops are almost perfect substitutes due to their similarities in both, growing cycle parameters and agro-ecological requirements.

[6] As a matter of fact, soybeans can be planted in any land where maize grows well. In some special agroecological environments, the opposite is not always true.

[7] Tellería G. (2010)

2.3 Maize-soybeans-maize-soybeans-wheat/soybeans (double cropping).

3. For the "Corn Belt" region in the United States, the suggested rotation scheme is: soybeans-maize-soybeans[8].

For the purpose of covering with the analysis a wider geographical area and, at the same time, to facilitate inter-country comparisons, it will be assumed that the not inclusion in the RLAI of the area with wheat in the double cropping schemes does not significantly alter the results.

In other words, the simplified sustainable cropping system could be adequately represented, for those countries in the Americas that grow both crops, by the rotation scheme maize-soybeans-maize.

2.2 Countries included in the study

In the Americas there are three players that have a strong presence in the international soybeans market and, as a consequence, they are treated, in trade models, under the large country assumption (they face elastic excess demand curves and influence world prices). Those countries are the United States, Brazil and Argentina and, thus, all three should be given special consideration.

There are two other countries that, although they are smaller scale players, should be taken into account due to their growing presence in the soybeans international market, as well as to the relatively recent dynamism exhibited by the farming sector of those countries: Paraguay and Bolivia. These five countries were included in this study.

The RLAI was computed for all of them for the 1980/81-2011/12 period and a trend line was estimated for each one of the time series of the above mentioned index.

2.3 The RLAI and the release of glyphosate-tolerant soybean varieties

Next, a simple linear regression model was run, with the RLAI as the dependent variable and a dummy as the sole explanatory variable, so as to control for the date at which the glyphosate-tolerant GM varieties were made commercially available to farmers (legally or otherwise) in each one of the countries under analysis (1996 for the US and Argentina and 1998 for the remaining three countries), in order to make inferences regarding the causality of this particular event in the "soyafication" process where it has been observed.

The linear regression model used has the following expression:

$$RLAI\ (t) = C + Dummy\ (t) + e$$

[8] Erickson, B. Y Lowenberg-Deboer, J. (2005).

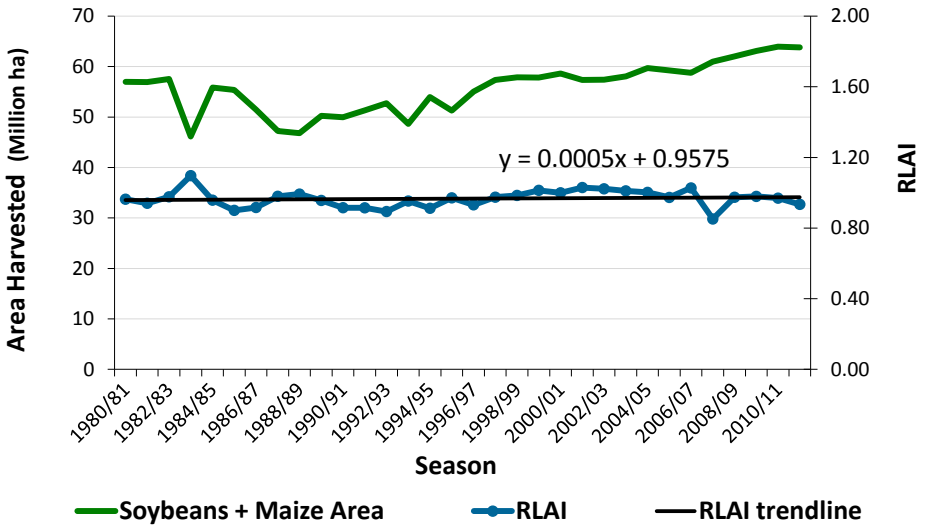
3. Results

3.1 Comparative analysis

3.1.1 United States

This country appears to be the best example of optimum allocation of land between soybeans and maize (from the sustainability of the cropping systems perspective and given the assumptions made in this regard). As it is shown in Figure 2, RLAI values remain very close to 1.0 during the entire period under analysis. Naturally, the resulting trend line is flat. This cropping system appears to be operating in the neighborhood of a long-term equilibrium point, with marginal deviations from trend, which are to be expected as a consequence of planting decisions made by farmers in response to changes in relative prices. But it can also be inferred that the agronomically recommended rotation scheme (maize-soybeans-maize) has a very strong influence in those decisions, which could mean that intergenerational concerns have been internalized by farmers. The US has not been affected by "soyafication" (if there is a bias, it is in favor of maize).

Figure 2. *UNITED STATES: Area harvested with soybeans + maize vs. RLAI (1980/81-2011/12)*



Source: The authors based on data from FAOSTAT[9] Database and USDA's Foreign Agricultural Service, Official Estimates[10] (2012).

3.1.2 Argentina

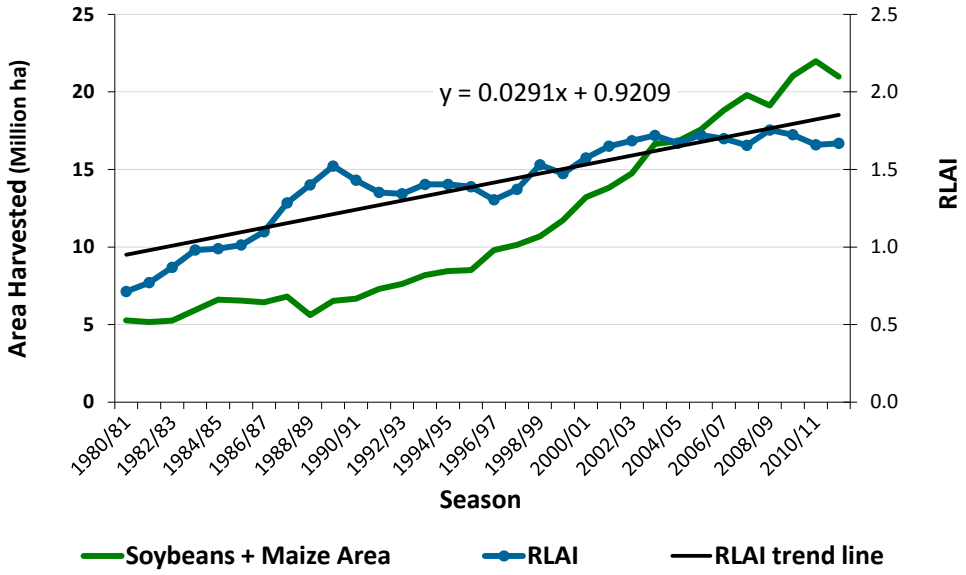
The expansion of the area with soybeans, without a parallel growth in the area with maize starts in 1986/87, the point in time in which the RLAI takes on a value of 1.10 and keeps moving upwards until it reaches its highest point in 2008/09, with a RLAI of 1.75 (see Figure 3). The trend is positive at an annual rate of 3%. The increase in output for the period under analysis was an astonishing 1001% (3.77 million tons in 1980/81 and 41.50 million tons in 2011/12) and it is explained, mostly, by the expansion of the planted area with soybeans (863%) and, to a lesser extent, by an increase in productivity (18%). There is a caveat,

[9] United Nations' Food and Agriculture Organization, FAOSTAT Database. Data available online at: http://faostat.fao.org/

[10] Data available online at: http://www.fas.usda.gov/psdonline/psdquery.aspx

nevertheless. It refers to the fact that the technological change represented by the glyphosate-tolerant GM varieties made it possible to grow soybeans in areas (previously dedicated for the most part to low productivity livestock) where that was not feasible before the availability of these new materials. Thus, although it is not easy to capture this contribution of the new technology to the increase in the productivity of land, it is safe to assume that it explains significantly more that 18% of the growth in output. As mentioned in the introduction section, the rate at which soybean planted area expanded after 1996 (when GM varieties were first available) tripled from the values observed up to that year. Thus, two-thirds of the 863% increase in production attributed to growth in planted area[11] might be causally linked to the new technology, in synergy with no-till cultivation practices whose adoption dynamics were very similar to that of GM soybeans.

Figure 3. *ARGENTINA: Area harvested with soybeans + maize vs. RLAI (1980/81-2011/12)*



Source: The authors based on data from MAGyP (2012).

3.1.3 Brazil

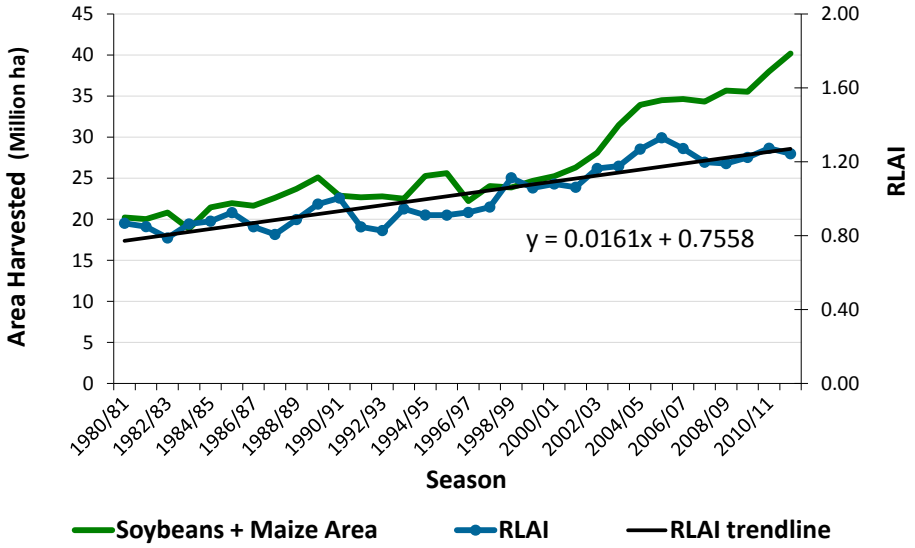
In the case of Brazil, the deviation from the assumed land allocation equilibrium represented by a RLAI of 1.0, starts in 1998/99 (see Figure 4), when that index takes on a value of 1.11. That season coincides with the availability to farmers of gliphosate-tolerant soybean seed (introduced from Argentina, it had not been released in Brazil yet). The process reaches its peak in 2005/06 (RLAI=1.33) and, from there on, it appears to start a slowly descendent trend that bottoms out at a RLAI=1.19 in 2008/09, although it climbs back up to 1.27 in 2010/11.

The trend line is upward sloping at a 2% annual rate, lower than the one estimated for Argentina (3%).

The production of soybeans increased by 332% over the 32-year period, resulting from an increase of productivity of land of 52% and an expansion of cultivated area of 185%.

[11] This increase in planted area is composed of a real component and a virtual one, the latter (up to 4 million hectares) being the expansion of the double-cropping system (wheat/soybeans as a second crop) in the Pampean Region and the former, mostly the expansion into marginal areas.

Figure 4. *BRAZIL: Area harvested with soybeans + maize vs. RLAI (1980/81-2011/12)*

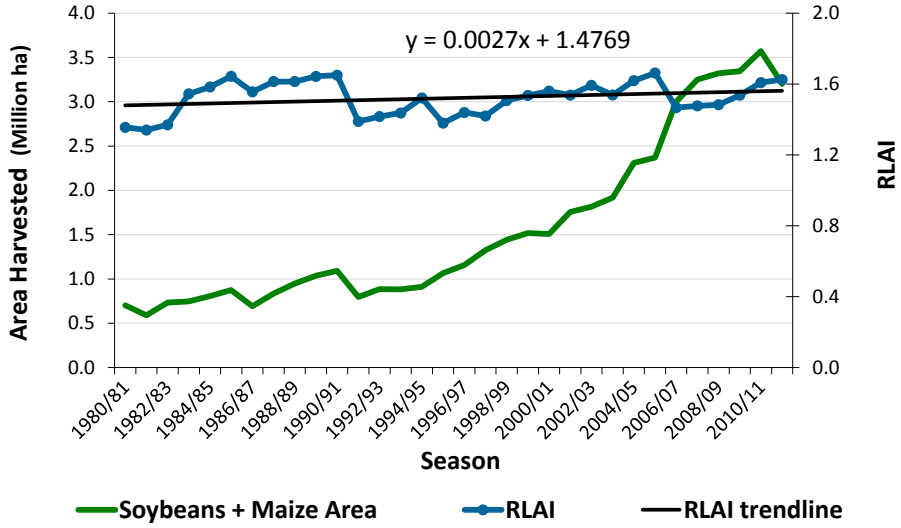


Source: The authors based on data from FAOSTAT Database and USDA's Foreign Agricultural Service, Official Estimates (2012).

3.1.4 Paraguay

A review of the values of the RLAI for this country suggests that the "soyafication" process started at some point in time before the beginning of the series under analysis, given that, for the 1980/81 season, the RLAI stands at 1.36 (see Figure 5) and, after that, it takes on values that move within a narrow range, reaching its maximum in 2005/06 (1.66). The trend line is flat, just like it happens to be in the case of the United States, but the implications are quite different, since the area planted with soybeans + maize has had a five-fold increase over the period under analysis, but the allocation of land between those two competing crops remained remarkably stable, implying the existence of a long-term sustainable disequilibrium (given the assumptions made about the optimum allocation pattern).

Figure 5. *PARAGUAY: Area harvested with soybeans + maize vs. RLAI (1980/81-2011/12)*

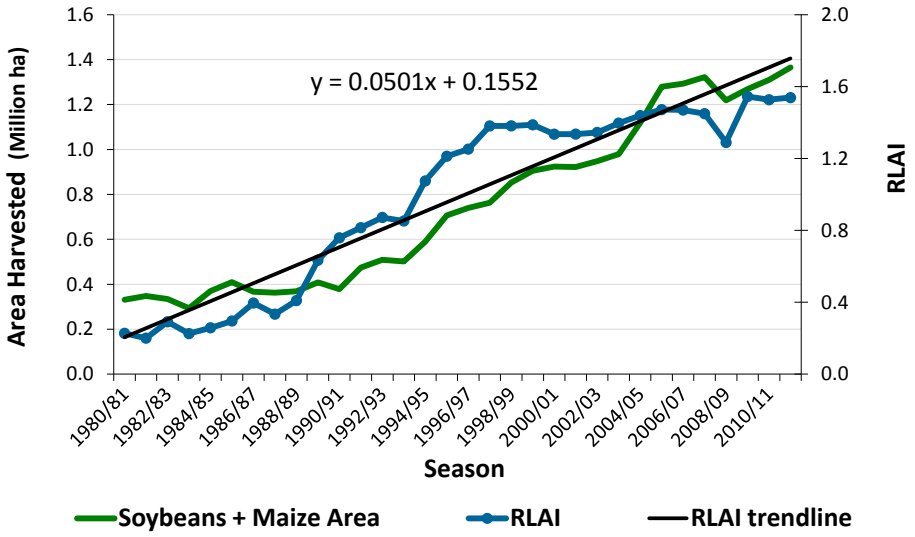


Source: The authors based on data from FAOSTAT Database and USDA's Foreign Agricultural Service, Official Estimates (2012).

3.1.5 Bolivia

The evolution of the RLAI in this case is clearly different from the story told by the same index in Paraguay (see Figure 6). The RLAI takes on a value of 0.23 in 1980/81, which implies a strong disequilibrium but in the opposite direction. That is, far more land was allocated to maize than to soybeans. The RLAI stays around those values until late into the 80's and it enters into the "soyafication" zone in 1994/95 (1.07) and reaches its maximum value in the seasons 2009/10 and 2011/12 (1.54). The area planted with soybeans grew exponentially (2694%) during the period under analysis but it was not at the expense of the area with maize, that remained virtually constant. More location-specific data, on both, agro-ecological conditions and soil characteristics of the new agricultural frontier will have to be collected and analyzed before any conclusions can be reached as to the long-term sustainability of this almost 28-fold expansion of the area with soybeans.

Figure 6. *BOLIVIA: Area harvested with soybeans + maize vs. RLAI (1980/81-2011/12)*



Source: The authors based on data from FAOSTAT Database and USDA's Foreign Agricultural Service, Official Estimates (2012).

3.2 Regression statistics

Tables 1 and 2 show the key regressions statistics generated after running the simple linear model described in section 2.3 to control for the release date of the glyphosate-tolerant soybean varieties for the five countries under analysis.

Table 1. *Regression statistics*

Country	Brazil	Bolivia	Argentina	Paraguay	United States
Multiple correlation coefficient	0.91	0.80	0.73	0.30	0.29
Coefficient of determination R^2	0.82	0.63	0.53	0.09	0.08
Adjusted R^2	0.82	0.62	0.52	0.06	0.05
Typical error	0.07	0.31	0.21	0.09	0.05
Observations	32	32	32	32	32

Source: The authors, based on data from MAGyP, FAOSTAT and USDA (2012).

Table 2. *Coefficients and significance*

Country	Brazil	Bolivia	Argentina	Paraguay	United States
Intercept	0.89	0.64	1.19	1.50	0.95
Variable RLAI	0.30	0.78	0.43	0.06	0.03
p	9.47E-13	5.18E-08	1.98E-06	0.0901	0.1118

Source: The authors, based on data from MAGyP, FAOSTAT and USDA (2012).

4. Discussion and conclusions

Table 3 summarizes, for the season 2011/12, the status of the process of "soyafication" in five countries of the Americas, which offers a variety of situations. Argentina leads the ranking, followed by Paraguay, Bolivia and Brazil. The United States is the only country in the group that virtually doesn't show any deviations from the value of RLAI assumed to be correlated with a sustainable allocation of land between soybeans and maize (1.0)

Table 3. *Soyafication ranking for 2011/12*
(Deviations from RLAI=1.0)

	Country	Deviation
1	Argentina	+0.67
2	Paraguay	+0.63
3	Bolivia	+0.54
4	Brazil	+0.24
5	United States	-0.07

Source: The authors, based on data from MAGyP, FAOSTAT and USDA (2012).

If we compare the slopes in the trends of the RLAI (see Table 4), the positions in the ranking of Table 3, which is basically a "photograph" of the 2011/12 status, change significantly. Bolivia moves to the top of the ranking, with an annual rate of increase of the RLAI of 5%. Second place is for Argentina, with 3% and third for Brazil, with 2%. Both Paraguay and the Unites States are tied for the forth place with flat trends (0%), but for very different reasons: Paraguay became strongly "soyafied" at least three decades ago and the resulting allocation of land to soybeans and maize has remained stable during all the period under analysis. The RLAI for the United States, on the other hand, remained very close to the assumed long-term sustainable allocation ratio between these two crops.

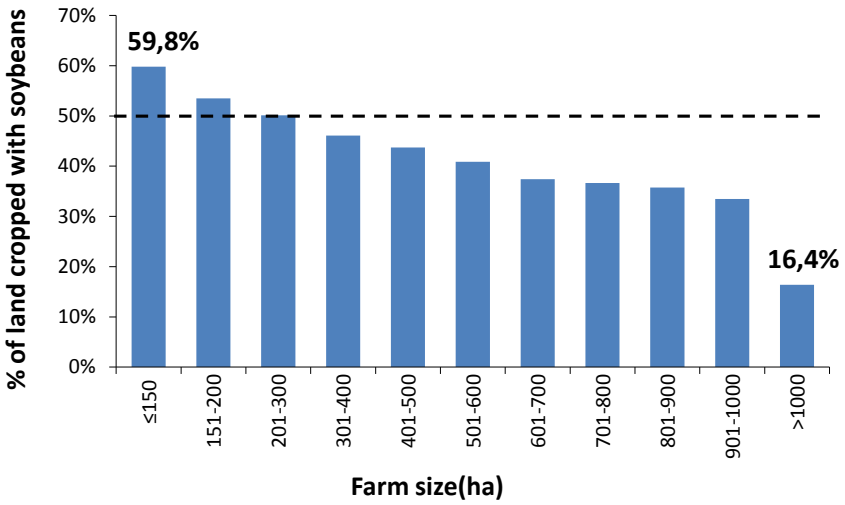
Table 4. *Ranking of soyafication trends (1980/81-2011/12), Annual rate*

	Country	Δ RLAI/year
1	Bolivia	+0.05
2	Argentina	+0.03
3	Brazil	+0.02
4	Paraguay	0.00
4	United States	0.00

Source: The authors, based on data from MAGyP, FAOSTAT and USDA (2010).

As to the results of the regressions of the RLAI values against a dummy variable that takes on the value of 1 starting from the year that marks the availability to farmers of the glyphosate-tolerant soybean varieties, the high adjusted R^2 for Brazil (0.82), suggests that this specific technological change had, in this country, a relatively higher effect on the process of "soyafication" than it did in Argentina (with an adjusted R^2 significantly lower, of 0.52). This finding should not be surprising since, according to Trigo and Cap[12], small farmers in Argentina had already chosen to "soyafy" their cropping systems in 1988; 8 years before the glyphosate-tolerant GM varieties were available (see Figure 7). For farm sizes under 100 hectares, the implicit RLAI for that year was therefore, 1.40 (assuming the only two summer crops included in the system were soybeans and maize).

Figure 7. *ARGENTINA: Farm size and percentage of available land cropped with soybeans (Pampean Region, 1988)*



Source: Trigo, E. and Cap, E. (2006).

[12] Trigo E. and Cap E. (2006).

The asymmetry of situations between Bolivia (with an adjusted R^2 of 0.62) and Paraguay (with an adjusted R^2 of 0.06) is remarkable. From these statistics it could be inferred that, *ceteris paribus*, in Paraguay, maize was not left in a disadvantageous position relative to soybeans in land allocation patterns, at least as an effect of the availability to farmers of the GM soybeans varieties, as it appears to have happened in Bolivia, where the area planted with maize remained almost constant, but this crop did not contribute to the expansion of the agricultural frontier, that was the consequence of the increase in area planted with soybeans. Again, additional location-specific data will be needed to better assess the causal relationships of these technology-induced transformations.

In summary, the process of "soyafication" appears to have taken place (with variations) in all four soybean producing countries of the Southern Cone of South America and, in three of them (Brazil, Argentina and Bolivia) it can be explained, in good part, by the commercial availability to farmers of GM soybean varieties.

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