The development of Brazilian agriculture and future challenges[1]

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Introduction

Over the last four decades, Brazilian agriculture has stepped up to the challenges posed by society. In the 1970s, the four major challenges posed on the sector were: 1) to ensure food supply at reasonable prices, especially for cities that were undergoing heavy migratory flow from the rural population[6]; 2) to foster the development of the interior of Brazil, generating jobs, income and welfare to the rural population; 3) to ensure the occupation of the Brazilian territory and to preserve the Brazilian base of natural resources ; 4) to create production surplus to export, generating financial resources to boost other sectors of the economy.

At that time, the primary objectives of Brazilian agricultural policies[7], from the point of view of groups favored by society, were particularly challenging. According to Hayami and Godo (2004), countries with intermediate income level have a challenging agricultural policy, as on the one hand they must guarantee low prices for urban workers, and on the other they must prevent rural producers' level of income from decreasing.

For the future, the challenges for Brazilian agriculture are equally relevant. A macroeconomic environment with solid fundamentals that are transparent and predictable in key variables (inflation, exchange rate) is obviously one of the core aspects, as well as improvements and expansion in infrastructure (transport and storage) and increasing exports. These factors guarantee competitiveness to the sector in face of world competitors and enable the production potential of Brazilian agriculture to be fulfilled in face of the higher global and domestic demand for food, fibers and biofuels.

However, in a future perspective, just increasing production is not enough; the expansion of agricultural production should follow sustainability criteria that include technical-economic, social, and environmental dimensions. The priority action is to prevent the agricultural frontier from expanding via continuous gains in agricultural productivity, and to foster the substitution of low-productivity pastures with other more productive agricultural and forestry uses.

Criteria for technical-sanitary standards for agricultural production in Brazil are added to

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[6] According to IBGE, the Brazilian population in 1960 was 70 million people, of which 45% were considered urban. In 1980, the population had increased to 119 million and 68% was urban. In the period from 1960 to 1980, the Gross Domestic Product (GDP) had an impressive yearly growth rate of 7.54%, which caused the demand for food to increase even more, especially by those that positively respond to income increase.

[7] According to Mueller (2007), agricultural policies can be classified as: 1) quantitative policies, encompassing stimulus policies (market stimulus with minimum prices, subsidies, taxation, insurance, etc., and rural credit) and policies for specific products; 2) qualitative policies that focus on structural changes, such as land use, infrastructure and technological development.

these requirements. An example is the adoption of production technologies and systems that reduce greenhouse gas emissions, the so-called low-carbon agriculture, which is becoming stronger and should be a core point to consider in the next decade for the expansion of Brazilian exports to better paying markets. In effect, sustainability and good practice criteria for agricultural production should be taken seriously by the domestic production sector in order to solve any form of negative pressure posed on Brazilian exports, either in terms of loss of value or of export volume.

This article is structured in four sections, the first of which is this introduction. In the second section we explore some aspects of the development style of Brazilian agriculture over the last 40 years[8]. In section three, we focus on the determining factors of the production capacity of Brazilian agriculture. In the fourth and last section, we discuss the challenges and opportunities to consolidate a leading position for Brazilian agriculture in the global scenario.

The style of development of Brazilian agriculture

The development of Brazilian agriculture since the 1970s has been strongly based on the generation of science for the tropical environment and on the increased incorporation of technologies developed for the production process. These significant technological advancements brought a series of socioeconomic and environmental benefits for Brazil.

Expansion of food supply

Until the 1970s, a considerable share of food security[9] in Brazil was guaranteed by imports. From the end of the 1960s, but especially during the mid-1970s, structural changes were made to the Brazilian agricultural sector that in the following decades helped build Brazil's food self-sufficiency, except in the case of wheat. Brazilian entrepreneurs took on the challenge of producing with competitiveness in the agricultural frontier (Cerrado region). The availability of natural resources in the Cerrado region and the investments made by the federal government in basic infrastructure, in science and technology for tropical agriculture, and in agricultural policy instruments such as rural credit made it possible to incorporate modern technologies to production systems, thus determining a significant increase in food supply without the need to proportionally expand the agricultural area (Figure 1).

Food supply in Brazil increased at higher rates than (domestic and exports) demand, and for this reason food prices fell dramatically. Figure 2, adapted from Alves et al. (2008), shows the evolution of the balance between supply and demand over the last four decades. The demand for food grew significantly since 1975, going from D_{1975} to D_{2010}. The main factor that induced the shift from D_{1975} to D_{2010} was the growth of per capita income, especially in poorer countries and regions. Urban population growth was also an important factor that influenced the shift of the demand curve to the right.

If there had been no technological advancement during the period studied in Figure 2, the new equilibrium price would occur at point b, where curve S_{1975} crosses curve D_{2010}; the consequently increase of prices would be provided by segment ab. Under this scenario, there would have been a large transfer of income from consumers to farmers. However, in the period 1975–2010, the green revolution spread and was consolidated throughout Brazil, and the technological development of tropical agriculture shifted the supply curve from S_{1975}

[8] For further information about the evolution of the Brazilian agricultural sector read Contini et al. (2010) and Gasques et al. (2010).

[9] According to the Food and Agriculture Organization of the United Nations (FAO) (2009), food security exists when all persons at all times have physical or economic access to food, that must be not only safe (free of toxic substances, contaminants, etc.) but should be quantitatively and nutritively adequate to meet dietary needs and preferences of the individuals to have an active and healthy life. Food security encompasses four dimensions: 1) availability: focuses on food production; 2) access: the ability of people obtaining food, from production, buying or transfer; 3) use: relevant issues address the nutritional value, the safe food and interaction with physiological conditions; 4) dietary system stability: supply and stable access to food with capacity to respond to food emergencies.

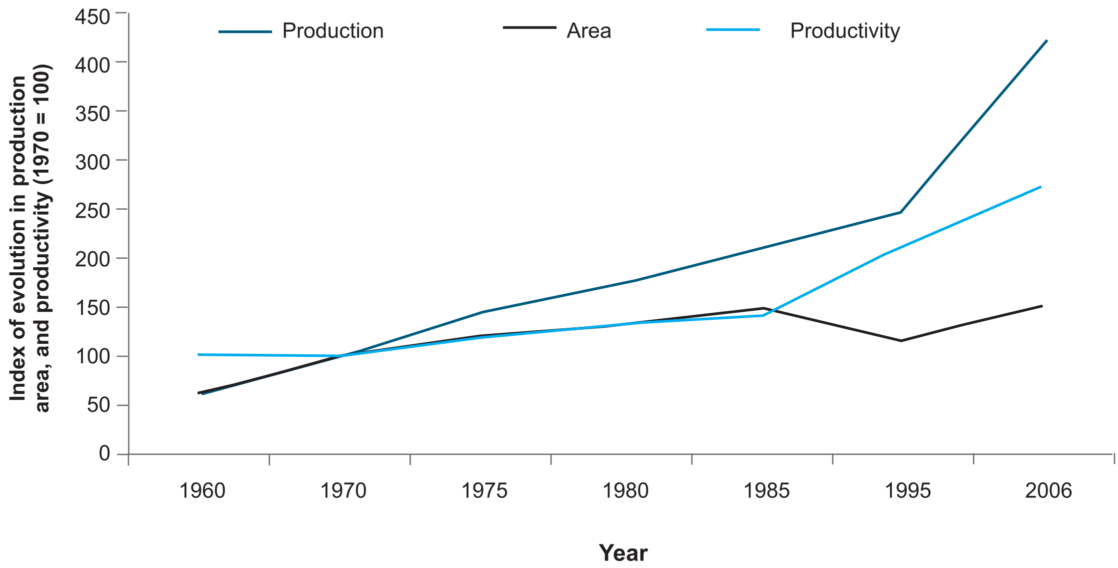

Figure 1. Evolution in production, area and productivity of the five major grain and oilseed crops (rice, beans, maize, soybean and wheat).

Source: data from IBGE's (2009), author's calculations.

to S_{2010}. In contrast with the initial equilibrium price in 1975 (point a), the decrease in price was equivalent to segment cd. If measured correctly, price reduction would be ba + cd.

Reduction in food price and income effect

Food production has increased at higher rates than food demand over time while food prices have decreased. Using historical data on food prices from Dieese, concerning a food basket for the city of Sao Paulo, Brazil, we found that the price of this food basket in April 2010 represented, in real terms, around 53% of the price paid by consumers in January 1975. In 35 years, food price to consumers has decreased by half, which greatly reflects the expansion of the agricultural production in Brazil. Even when the food price peaked in 2008, it had a very small impact on the prices paid by consumers (Figure 3).

The greater food supply that resulted from technological gains throughout the period, as well as the deregulation of markets in the 1990s, determined two very important effects to society. A very important one was a significant transfer

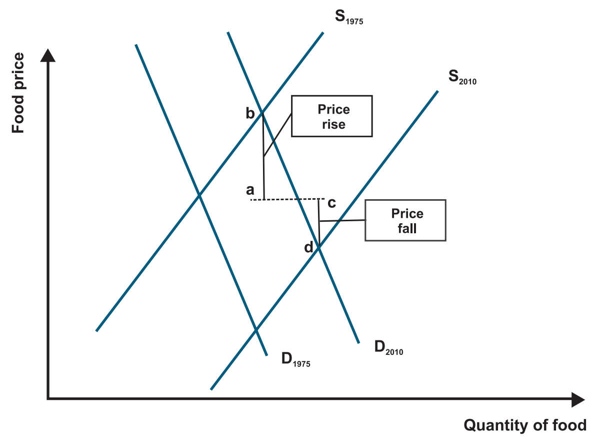

Figure 2. Dynamics of agricultural prices in Brazil for the period 1975–2010.

Source: adapted from Alves et al. (2008).

of income from farmers to consumers, as shown in Figure 4.

Under this scenario of supply growing at faster rates compared to demand, consumers benefit because they can either buy the original quantity of food (Q_0) at lower prices (P_M instead of P_0) or increase their food consumption to a higher level Q_d (Figure 4). The net welfare gain for consumers is equivalent to the *abfc* area,

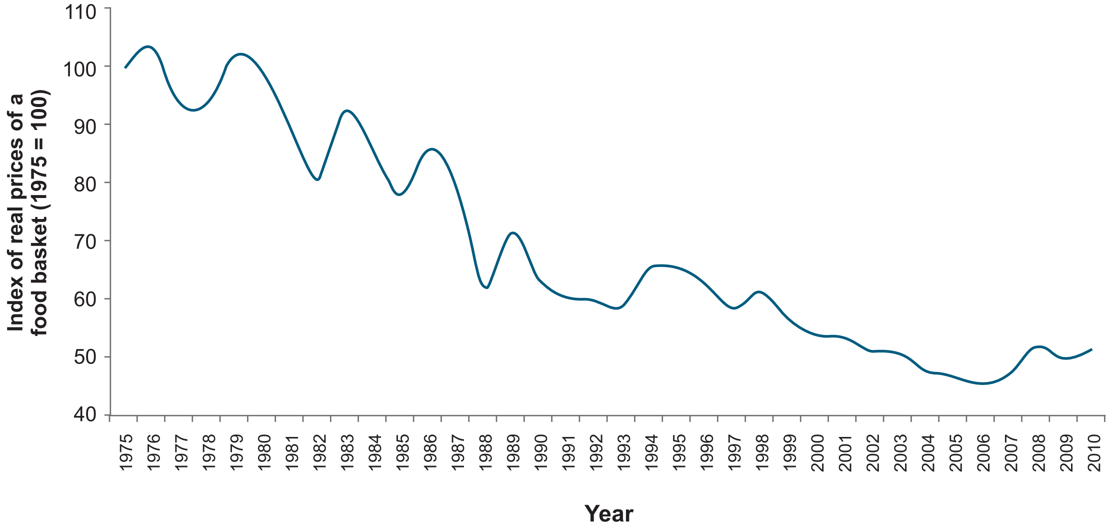

Figure 3. Real price index for a food basket in the city of São Paulo, January 1975–April 2010.

Source: data from Dieese (2010), author's calculations.

which represents the increase in consumer surplus resulting from the decrease in food prices.

Gains in consumer surplus took place partially due to lower income for Brazilian farmers. Initially, farmers' gross income is shown in area *abjg*; assuming that the supply curve measures marginal costs, the cost for producers is shown in the area under the supply curve (*bjh*), and producers' surplus (net income) is equal to the difference, *abhg*. When food price falls from P_0 to P_M, farmers' net income is reduced from *abdc* to *cdhg*. This loss in producer surplus – *abdc* – represents the contribution (income transfer) from farmers to consumers. Barros (2006) estimated that in the decade that followed the Real Plan, this transfer might have exceeded R$ 1 trillion. According to the author, income transfer from the rural area to consumers seems to have stabilized at around R$ 150 billion annually.

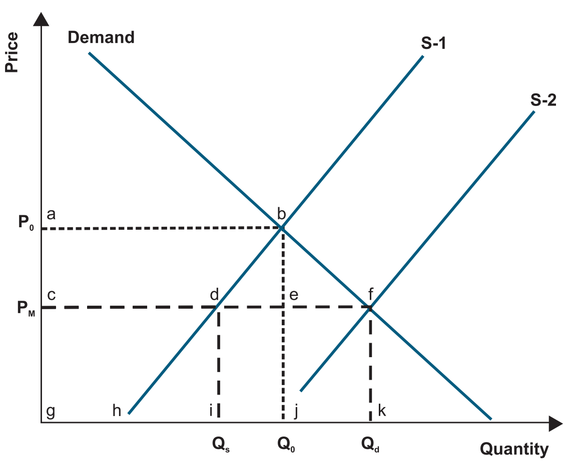

Figure 4. Effect of increased food supply (from S-1 to S-2) and decreased food price (from P_0 to P_M) on producer and consumer surpluses.

Source: adapted from Timmer (1986).

Another very important effect resulting from lower food prices is the so-called income effect that increases purchasing power, especially of the poor, who spend a greater portion of their income to buy food. When food prices decrease and remain stable, as in the case of Brazil, a larger share of income is allocated to buy non-food items, boosting other sectors in the economy.

Labor, income and welfare generation in rural areas

Despite the fact that agribusiness might still have an outstanding position in the economy of a more developed country, the relative economic importance of the agricultural sector decreases vis-à-vis the industrial and service sectors. The gradual reduction of the agricultural sector's share in the composition of the GDP and of the labor force in Brazil is unavoidable (Table 1). Notwithstanding, agriculture in Brazil is still an important sector for labor and income generation. Recent estimates made by Nassif et al. (2008), using the New Model for Labor Generation of the Brazilian Development Bank (BNDES), show that in 2007, for a R$ 10 million increase in agricultural production, a potential of 1,054 job openings was generated (440 via direct effect, 169 via indirect effect and 445 via income effect).

The most dynamic agricultural regions were capable of generating more income and welfare in rural areas. For example, in 2004, the highest GDP per capita in dynamic agricultural microregions in the Brazilian Cerrado was in Parecis (R$ 28,756.00), in Mato Grosso, with per capita GDP almost 13 times higher than the Jalapão microregion (R$ 2,218.70) in Tocantins (MUELLER; MARTHA JÚNIOR, 2008).

The Human Development Index (HDI) is a more comprehensive development indicator. It was created in response to the frequent criticism on the use of GDP per capita, or per capita income, as a development indicator. The assumption is that to measure the socioeconomic progress of the population of a given country or region, it is not enough to take only the economic dimension into account; it is necessary to further take into account other social characteristics such as education and life expectancy, which together better translate the quality of life of the population.

In a recent assessment, Mueller and Martha Júnior (2008) identified that the expansion of agriculture in dynamic agricultural regions in the Cerrado seems to have been an important factor to obtain improved HDIs. Taking the 0.766 value for Brazil's HDI in 2000, and the 10.1% growth rate

Table 1. Brazil's gross domestic product (GDP) and per capita GDP adjusted by the purchasing power parity (PPP), and share of different sectors in the GDP and in the composition of labor force.

Brazil	GDP – PPP (US$ billion)	GDP/capita – PPP (US$ 1,000)	% GDP			% labor force		
			Agric.	Ind.	Serv.	Agric.	Ind.	Serv.
World	65,960.00	9,990.57	4.0	32.0	64.0	40.7	20.5	38.8
Mozambique	29.17	1,395.32	21.1	30.9	48.0	81.0	6.0	13.0
Nigeria	191.40	1,417.45	17.3	53.2	29.5	70.0	10.0	20.0
Brazil	1,655.00	8,710.04	8.0	38.0	54.0	20.0	14.0	66.0
Russia	1,746.00	12,349.89	5.3	36.6	58.2	10.8	29.1	60.1
India	4,164.00	3,685.39	19.9	19.3	60.7	60.0	12.0	28.0
China	10,210.0	7,724.01	11.9	48.1	40.0	45.0	24.0	31.0
Chile	202.70	12,447.24	5.9	49.3	44.7	13.6	23.4	63.0
Mexico	1,149.00	10,570,29	3.9	25.7	70.5	18.0	24.0	58.0
South Africa	587.50	13,352.93	2.6	30.3	67.1	30.0	25.0	45.0
Indonesia	948.30	4,040.58	13.1	46.0	41.0	43.3	18.0	38.7
United States	13,060.00	43,368.54	0.9	20.4	78.6	0.7	22.9	76.4
Japan	4,218.00	33,099.62	1.6	25.3	73.1	4.6	27.8	67.7
France	1,902.00	29,852.19	2.2	20.6	77.2	4.1	24.4	71.5
Germany	2,632.00	31,941.36	0.9	29.1	70.0	2.8	33.4	63.8

Source: CIA (2007).

from 1991 to 2000, the authors verified that the performance for every region within the dynamic agricultural region in the Cerrado was highly favorable. In fact, the HDI of 22 out of 41 microregions assessed was above the national index average, while the HDIs of other eight microregions located below the national average were very close to it. Furthermore, HDI increase rates between 1991 and 2000 for most microregions were higher (in average, 15%) than the 10.1% for Brazil. Lower average rates were concentrated in micro regions that already had higher HDIs in 1991, such as the *Triângulo Mineiro*. Mueller and Martha Júnior (2008) noted that with economic growth, actions to improve education and services that lead to positive effects in health are obvious in poorer regions.

Expansion of exports

Exports of agricultural products such as sugar, cotton and coffee have historically had outstanding importance for the Brazilian economy. In the last decade, however, the diversification and dynamism of international trade were outstanding. In 1965, 52.5% of Brazilian exports were based on a single product – coffee – and agribusiness exports accounted for 84.4% of Brazil's total exports (RODRIGUES, 2008). In 2009, Brazilian exports totaled US$ 64.76 billion and represented 42.5% of total exports. The agribusiness export in the last decade is shown in Table 2; it reflects a higher participation of soybean, meat, the sugar-ethanol complex, and the forestry sector.

Until the mid-1990s, Brazilian agriculture strongly responded to the stimulus of the domestic market. However, over the last 15 years a growing share of Brazilian agricultural products was exported. This expressive surplus for exports has guaranteed positive results for the Brazilian trade of balance, supported food prices in the domestic market, and from a global perspective, reflected an important contribution from Brazil to reduce world hunger and macroeconomic (inflationary) pressures.

Table 2. Composition of Brazilian agribusiness exports.

Main exports (products)	1999		2009		1999–2009
	Quantity (US$)	Share (%)	Quantity (US$)	Share (%)	Variation in quantity (%)
Soybean complex	3,760,985,495	18.4	17,239,708,452	26.6	16.45
Meat	1,941,805,477	9.5	11,787,226,918	18.2	19.76
Sugar-ethanol complex	1,976,541,316	9.6	9,715,970,941	15.0	17.26
Forestry products	3,855,472,900	18.8	7,222,871,949	11.2	6.48
Coffee	2,463,875,421	12	4,278,940,375	6.6	5.67
Tobacco and byproducts	961,237,046	4.7	3,046,032,052	4.7	12.23
Leather, leather byproducts and furs	1,781,357,173	8.7	2,041,065,835	3.2	1.37
Cereals, flours and powders	65,377,111	0.3	1,818,558,831	2.8	39.45
Fruit juices	1,290,054,652	6.3	1,751,827,613	2.7	3.11
Fiber and textile products	673,464,336	3.3	1,260,339,975	1.9	6.47
Other products	1,723,833,825	8.4	4,593,088,278	7.1	10.30
Total	**20,494,004,752**	**100.0**	**64,755,631,219**	**100.0**	**12.19**

Source: Agrostat (BRASIL, 2010a).

Preservation of the natural resource base: the example of the land-saving effect

Brazil is nowadays an agricultural power that has been expanding and consolidating its agriculture with a moderate level of biome anthropization. For example, according to Project Probio (PROJETO..., 2007; BRASIL, 2007), coordinated by the Ministry of Environment (MMA), anthropization in the Amazon and in the Cerrado regions in 2002 was of only 9.50% and 38.98% of the area of each biome, respectively. These data are continuously updated and improved. Recent estimates for 2008 pointed out that the Cerrado region, for example, had 51% of its area preserved with original vegetation (VIANA, 2010).

These moderate levels of anthropization reflected the development of technologies for agricultural production in the tropical environment. This style of growth in the Brazilian agriculture, based on productivity gains, has enabled a significant land-saving effect. Calculations made by the Brazilian Agricultural Research Corporation (Embrapa), identified in Table 3, show that because of productivity gains in Brazilian agriculture over the last 35 years, the area that has been spared exceeded 250 million hectares. This certainly is an important contribution from agriculture to environmental sustainability.

Table 3. Spared area of Brazilian agriculture, in 1,000 ha.

Product	Current area	Δ factor	Projected area	Saving
Whole cottonseed	1,077	8.3814	9,030	7,953
Paddy rice	2,875	2.7685	7,959	5,084
Coffee	2,216	2.0049	4,443	2,227
Sugarcane	8,141	1.7243	14,038	5,897
Beans	3,993	1.3895	5,548	1,555
Corn	14,766	2.7545	40,673	25,907
Pasture	158,753	2.0760	329,571	170,818
Soybeans	21,313	2.4618	52,468	31,155
Wheat	1,852	2.2737	4,211	2,359
Other seven crops	1,430		2,829	1,399
Total	**216,416**		**470,770**	**254,354**

Source: data from IBGE (2009), calculation by A. Cavalcanti and E. Alves.

Determinant factors of the production capacity of the Brazilian agricultural sector

The production capacity of Brazilian agriculture has greatly evolved over the last four decades. Figure 5 shows the evolution in the per capita production of rice, beans, maize and soybeans. In 1970, the per capita production of products that are inelastic to prices and income, such as rice and beans, was 172 kg and 50 kg, respectively. In 2006, these figures increased to 301 kg in the case of rice, and 101 kg in the case of beans. For products that are more elastic to prices and income (and that have their demand sustained by increased demand for animal protein), such as maize and soybean, per capita production had an even higher increase: maize, from 417 kg in 1970 to 1,380 kg in 2006; and soybean, from 62 kg in 1970 to 1,329 kg in 2006. A significant share of soybean and maize production, around 60% and 85% of the total, respectively, remain in the domestic market, where a large portion is used in swine and poultry production (BRASIL, 2010b).

However, Brazilian agriculture did not only supply the domestic market. Growing shares of agricultural products are being exported (Table 2), thus helping strengthen Brazil's role in the word food market. In fact, in 1995, Brazil accounted for 5% of the world trade; in 2008, this rate increased to a significant 8%. Only the United States, with 18% of food exports in 2008 (compared to 23% in 1995), has individually greater relevance in world agricultural markets than Brazil (LIAPIS, 2010).

In order to keep Brazilian agriculture in this path of success, a series of challenges must

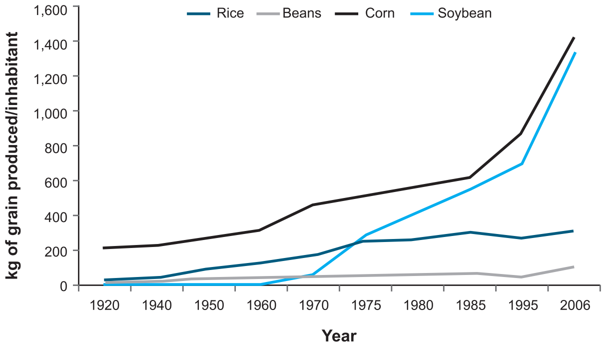

Figure 5. Evolution of per capita production (kg/inhabitants/year) of rice, beans, soybean, and corn.
Source: adapted from IBGE (2010).

be overcome. Some are related to the production capacity of agriculture. To address the production potential of agriculture, three important determining factors should be noted: human capital, technology generation and diffusion, and natural resources and weather.

Human capital

A considerable portion of the success of Brazilian agriculture over the last decades reflects the use of science-based knowledge and technology. The transfer of knowledge and technology occurs via a research system that carries out the required adaptations for a certain region (ALVES, 1985). This agricultural development strategy is further reinforced considering necessary future outcomes, keeping in mind the need to increase land and labor productivity in a possibly different and uncertain environment due to climate change.

However, knowledge and technology have little chances of being successfully adopted and used in large-scale in science-based production systems if minimum reading and math skills are limiting (RODRÍGUEZ et al., 2008). For example, at the operational level, how can the amount of fertilizer or seeds be adequately sized and how can the seed spreader be adjusted without minimum knowledge of math and if the service manual cannot be read? At a higher training level focusing on the decision-making process, basic theoretical knowledge and eventually the use of scientific methods are required (RODRÍGUEZ et al., 2008) to depart from the generally-accepted "rule of thumb" and to make the required adaptations in the production system.

A higher level of continuous education and training, both at basic and advanced levels, is required for better market placement, for an improved ability to make decisions, such as the perception of the opportunity cost, and lastly, for the perception of overall opportunities and risks. Thus, innovation in a firm depends on qualified human capital. Furthermore, with higher levels of education and with the strengthening of competences, gains in labor productivity increase, which in turn further boost average wages and income.

Technology generation and dissemination

In a science-based era, the generation of technologies is obviously an essential stage. Brazilian agricultural research has yielded high economic returns to society, totaling around 40% of internal rate of return (ÁVILA et al., 2010). In spite of this highly favorable economic result, investments are high and it takes a long time to repay them: usually 15–20 years depending on the technology. Then, the partnership between public and private research can help increase investments made in research, thus expanding the universe of knowledge and technologies available to farmers (ALVES, 2008).

Some key technologies that should eventually be funded are new plant varieties (adapted to non-native ecosystems, bred for higher productivity for a given environmental condition, resistance/tolerance to biotic and abiotic stress, and incorporating new tools such as biotechnology and nanotechnology); new inputs (machinery and equipment, fertilizers and agrochemicals); and new agricultural practices and innovative production systems, to accommodate more production cycles in a given year (two crop seasons per year), for instance, or to provide greater efficiency in water and nutrient use efficiency.

Another important focus is to increase or, depending on specific conditions, to maintain productivity gains that will enable the expansion of agricultural production, without the need to proportionally increase the area. In this context, an interesting parameter to assess the possibility of expanding agriculture, preferably via productivity and not through an increase in cultivated area, is the ratio between current (average and best producers) and potential productivity. For example, the average productivity of soybean currently is 3 t/ha. Top producers have been yielding average productivities of 4 t/ha; research results considering environmental limitations and the best technology available already showed a 6–7 t/ha potential. Hence, there still is room for growth before a yield ceiling is reached, as the yield gap between average and top producers is 43%–50% and 57%–67% of the productivity potential, respectively. Naturally, it is expected that under certain environmental and physiological limits, research can further increase these potential yields in the future, preventing farmers from reaching a theoretical roof in which additional food production can be obtained only through an expansion in agricultural area. In addition, some high-yielding technologies already available depend on higher relative prices for their large-scale adoption by farmers.

Obviously, after technology has been generated, it must be assessed with rigor and then be effectively disseminated. Alves (2001) proposed the following steps to assess agricultural technologies: a) provide a detailed description of the technology or knowledge; b) determine which technology will be replaced, clarifying the advantages and disadvantages of the new technology compared to the one currently in use in farms; c) detail the systems where the new technology can be applied and the need for (and the extent of) changes/adaptations in the current system; d) inform the costs of production of the new technology compared to the one in use which this new technology is supposed to replace, including price and climate risks; e) inform the new technology's potential response to modern inputs; f) inform if there are restrictions for adopting the new technology in terms of capital acquisition costs, education/training of the farmer, knowledge about technical service and credit limitations; g) identify the environmental impact of the new technology; h) when applicable, separate private from social costs and benefits.

From the viewpoint of capacity building and strengthening, it should be remembered that the low bio-economic performance of the production system may not be only due to farmers' limited use of technical assistance. In some cases, the difficulties that research and rural extension have in transferring the existing knowledge and recommendations into a language that can be understood by producers are also an important factor leading to unsatisfactory performance (MARTHA JÚNIOR; VILELA, 2007).

Natural resources and weather conditions

Agricultural production capacity depends on the availability of natural resources, on weather conditions (intensity and pattern of variation), and on the possibility of making changes in the production environment through the use of modern technologies. Relevant variables to be analyzed, which vary from region to region are: land availability; topography; soil fertility (in chemical, physical and biological terms) and soil texture; water availability and retention in soils; quantity and distribution of rains; temperature (intensity and variation); and light (intensity, variation, and photoperiod).

Thus, natural resources and weather conditions dictate what, where and when crops and pastures can be grown using a given technological package and considering some political and economic conditions. Here are some examples. Sugarcane finds favorable natural resource availability and weather conditions to express high yields in the Southeast and in some parts of the Cerrado but not in the Amazon biome; for this reason, over 90% of the expansion of sugarcane crops in the next decades will be concentrated in the western part of São Paulo and in the parts of the Cerrado that border this state. Soybean, in Mato Grosso, is competitive with other regions in Brazil and worldwide due to its high productivity levels and its lower costs of production. Thus, productivity reflects the availability of natural resources, weather conditions and the technologies adopted by farmers. Due to inherent characteristics of crops and pastures, in every area where a high-productivity crop (grains, oilseeds or fibers) can be grown, it is possible to implement integrated crop-livestock systems; however, these mixed crop-livestock systems cannot be efficiently implemented in every area where livestock is raised.

Favorable and unfavorable conditions for agricultural production

Given the availability of human capital, technology, natural resources and weather, some conditions can favor agricultural production capacity, both in terms of intensity and of timely response in supply. A good example are economic issues (supply and demand of agricultural products in the domestic and world market under different timeframes) and policies (macroeconomic, agricultural – incentives for rural producers, such as rural credit with competitive interest rates compared to international competitors, instruments for stabilizing farmers' income, risk management instruments, payment for environmental services –, or industrial policies with focus on agricultural inputs).

On the other hand, there are some conditions that can have negative effects as they could control or restrict agricultural production capacity. Some examples are: infrastructure (distribution and transport of agricultural products from the farm to the market and then to consumers, communication and information technology); legal aspects (labor legislation that can influence the competitiveness among activities and can possibly influence land use decisions, and environmental issues, such as agroecological and economic zoning, legal reserve and permanent areas of preservation regulations); economic issues (interest rates, taxation); and administrative efficiency (bureaucracy, exporting difficulties).

Addressing these conditions in detail is not the intention of this article; however, some examples can help illustrate the meaning and importance of those factors to boost or restrict agricultural production capacity over the next decades. One ought to consider initially positive factors, such as rural credit and competitive interest rates compared to international competitors.

The support given to the producer via agricultural policies is justified by the fact that agricultural markets combine uncommon characteristics that greatly affect supply and demand. In terms of demand, low own-price elasticity and low income elasticity are verified. In the short-term supply, a high dependence on weather conditions is observed; in the long-term, agricultural supply depends on technological innovations. In addition, there is the perfect competition nature of agricultural markets, which renders them unprotected against the acquisition of inputs in oligopsonic markets and the selling of products in oligopolized markets. Furthermore, the benefits reaped from investments made in Brazilian agriculture, as presented in the previous section, were not restricted to the sector, but rather, were largely transferred to society with positive effects over other sectors of economy.

Many investments in agriculture have positive economic results when international interest rates are used. The specificities of Brazilian macroeconomy, however, may turn the investment into a less attractive option compared to investments in the financial market. In other situations, even with the high interest rates practiced in Brazil, investments in agriculture are a viable option. However, negative cash flows at the start of a project (intensity and years of duration), which are incompatible with farmers' repayment capacity, entail giving up the investment or, in other cases, a less costly (but also less efficient) technology.

Thus, the availability of adequate funding in terms of volume of credit, period to repay the loan and competitive interest rates, from a social perspective, enables the expansion of food supply at more reasonable equilibrium prices. From the producer's viewpoint, adequate funding makes it possible for the benefit generated by technology to be accomplished at longer deadlines, increasing the opportunities for large-scale adoption of the technology and can eventually make it more inclusive as it can be adopted by producers with less capital. This situation is strengthened by the fact that when interest rates are more competitive, the risk premium for a given internal rate of return is higher, which may eventually boost the intensity and promptness of the supply response.

Let us consider a negative condition, such as taxation. The taxation of an economic activity is the launching pad for the very existence of the government, as it is a necessary source of resources so that the government can perform its role in society (TIMMER, 1986). Extremely high taxation, however, ends up undermining the competitiveness of the productive sector and the welfare of the population.

As in any other economic activity, agriculture is influenced by the incidence of taxes. A studied carried out by Fiesp/FGV-SP (2009) showed that agricultural commodities' price had an average 12% taxation. Specifically in the case of beef, sugarcane, soybean and maize, the fiscal burden identified in that study was of 15.56%, 10.45%, 8.04%, and 2.50%, respectively. It should be noted that as these products have different demand and supply elasticities (NEGRI NETO; COELHO, 1993), the percentage of tax accrued by producers and consumers will have a very different behavior. If the absolute value for own-price elasticity of demand is higher than supply elasticity, such as in the case for beef and chicken, then the farmer will bear a higher percentage of taxes. Likewise, when own-price elasticity is less elastic than supply elasticity, as the case of rice and coffee, the highest share of taxes will be borne by consumers.

In a future perspective, it is important to quantify the impact of these taxes considering different agricultural products, by regions, and to assess how productivity affects the impact of taxes in costs of production and competitiveness vis-à-vis other land-use alternatives. If tax burden positively responds to productivity increases, this can indicate that more efficient farmers might be progressively hindered by the agricultural tax system. Given the importance of the agricultural sector to Brazilian economy and that on average 22% of the population's income is spent with food items, research in this area can positively contribute to the decision-making process of public and private agents. And from a regional policy perspective, the impacts of agricultural fiscal policy can also vary depending on inherent regional characteristics (land-use, industrial activity).

Final considerations

In the next decades, Brazil will be strongly positioned as one of the great players in the production of food, fibers and bioenergy. Recent projections of the Organization for Economic Cooperation and Development (OECD) and the Food and Agriculture Organization (FAO) (OECD; FAO, 2010) report on agriculture for the next decade (Figure 6) have shown that in the period 2009–2019 the growth in Brazilian agribusiness should be 38%, twice the world average and higher than the growth projected for other important food producers: United States, Canada and Australia, around 10%; European Union, 4%; China and India, approximately 22%; and Russia and Ukraine, around 27%. These figures reflect vigorous growth rates for agricultural production in countries like Brazil (2.8% annually), Ukraine (2.3% annually) and Russia (2.1% annually) compared with traditional producers, such as the European Union (0.4% annually), Canada (0.8% annually) and the United States (1.0% annually). Australia, India and China would have intermediate annual growth rates 1.1%–1.7%.

The role of agriculture in fostering development and as an effective tool to guarantee food and energy security requires a systemic approach, adequate investments and coordinated efforts, that are often carried out by agents that have conflicting opinions about a given matter, to find sound solutions to the different challenges in the economic, social and environmental dimensions (MUELLER; MARTHA JÚNIOR, 2008). In the coming decades, although food production is still the main focus, the production process shall consider additional issues. Brazilian and world societies are becoming more and more concerned and demanding that other issues, such as environmental, food quality and safety issues, are included in the "production function."

The environmental dimension, including the use of biofuels, is getting stronger and bringing about new perspectives to the production model. For example, consider direct and indirect land use effects from biofuel production expansion vis-à-vis deforestation and the adoption of novelty low-carbon agricultural technologies. These variables must be incorporated into the usual technical and economic restrictions of the production function. It should be mentioned that the style of growth of the Brazilian agriculture has historically been based in land-saving technologies (Figure 1, Table 3), reflecting persistent productivity gains (GASQUES et al., 2010).

Recently, agricultural policies already indicate, via incentives, the importance of expanding the use of low carbon technologies. In the 2010–2011 Agricultural and Livestock Plan, of the Ministry of Agriculture, Livestock and Food Supply, the Low Carbon Agriculture (ABC) credit line has R$ 3 billion, with annual interest rates of 5.5%. In accordance with the Climate Change Law that was approved in December 2009, it is estimated that the agricultural sector (recovery of low-productive pastures, and stimulus to increase the adoption of integrated crop-livestock systems, use of biological nitrogen fixation and high-quality no-till planting) and the biofuel production will be able to reduce the greenhouse gas emissions from the baseline scenario by 226 Mt of CO_2-equivalent by 2020. This implies that the agricultural sector alone may be responsible for 21.5% of the mitigation actions proposed by the Brazilian government.

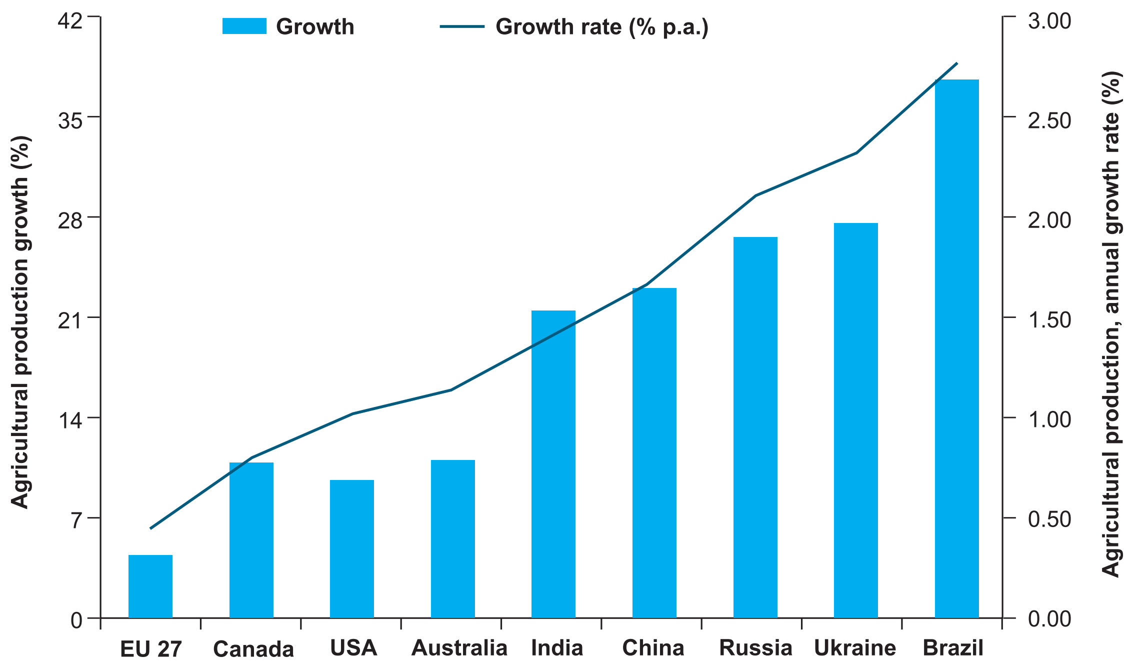

Figure 6. Agricultural production growth in selected countries and in the European Union (EU-27).

Source: OECD; FAO (2010).

However, the contribution of the agricultural sector may be even larger because of possible indirect spillovers arising from productivity gains and consequent land-saving effects. This may be a win-win situation because there are benefits under both socio-economic and environmental perspectives. On the one hand, the supply of food, fibers and bioenergy would be increased without new deforestation and, on the other hand, low productivity agricultural areas would be replaced by agricultural alternatives using modern and more efficient technologies. Clearly, catalyzing research-generated innovations implies ultimately in their adoption by farmers, which requires dynamic and well-trained private and public technical assistance. In such a scenario, the agricultural sector may indirectly contribute with an additional mitigation of 669 Mt of CO_2-equivalent by 2020 compared to the baseline scenario because of the avoided deforestation.

Meeting those requirements (and including social issues) that are growingly more demanding and that may determine the opening or restriction to markets that pay a better price for quality agricultural products will depend on the incorporation of modern technologies, which as a rule are more capital-intensive. However, the most severe restriction to boost the production capacity of the agricultural sector is human capital, in that it requires time to be removed. Capital restrictions embodied by the new technology are an outstanding deficiency, but they can be solved by a competent credit policy, while the access to more complex machinery and equipment can be solved by amending the rentaling and leasing legislation (ALVES, 2008).

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