Food and Nutrition Security in Brazil

Mass soybean harvesting at a farm in Campo Verde, Mato Grosso, Brazil © Shutterstock

Brazil

Coordinators
Evaldo Ferreira Vilela and Elibio L. Rech Filho

Participants
Geraldo Bueno Martha Junior
Eliseu Roberto de Andrade Alves
Mauricio Antônio Lopes
Élcio Perpétuo Guimarães
Paulo Renato Cabral
Cleber Oliveira Soares
Grácia Maria Soares Rosinha
Antônio Márcio Buainain
Marilia Regini Nutti
Geraldo Magela Callegaro

The impressively fast growing Brazilian Agricultural Production for domestic consumption and export is rooted in the intensive agricultural technology generation and adaptation by the dynamic Brazilian Agricultural Research System. This phenomenon has been widely admired, but only imitated by developing countries to a limited extent

Summary

Evaldo Ferreira Vilela[1] and Elibio Leopoldo Rech Filho[2]

In the past 40 years, the agricultural public and private sectors of Brazil have been working in close collaboration, to promote one of the most impressive and successful sustainable agricultural developments in a middle income country. Brazil has become an example of a food secure country and one the of world's most important agricultural export countries. Mention should be made of the outstanding role played by the agricultural research technology developed by Brazilian research organizations, led by the agricultural research system encompassing agricultural universities, the Brazilian Agricultural Research Organization (EMBRAPA) and the state agricultural research organizations.

This comprehensive executive summary outlines the future challenges and opportunities for the Brazilian agricultural sector in terms of science, technology and innovation, to keep agriculture improving its performance in a world that faces the enormous challenge of feeding a hungry population now and in the following decades. These challenges and opportunities were identified by a select group of highly qualified Brazilian researchers who have spent a lifetime generating and adapting new technology for the development of the Brazilian agriculture sector.

1. Brazil's National Characteristics

Geraldo B. Martha Jr.[3] and Eliseu Roberto de Andrade Alves[4]

Brazil's geographic, demographic and human capital characteristics

Brazil's geographic area is one of the largest in the world, totaling 8,515,767 km² distributed among 5,570 municipalities (IBGE, 2016a). Brazil makes a major contribution to global social and environmental services through its large expanses of land and water, representing 13.2% of the world's potential arable land (FAO, 2000) and 15.2% of the World's Water Resources (WRI, 2008). Over time, the country's

1. Chapter Coordinator; Professor at the Federal University of Viçosa (UFV); President of the Foundation for Research Support of the State of Minas Gerais (FAPEMIG); and Member of the Brazilian Academy of Sciences (ABC).

2. Chapter Coordinator; Senior Researcher at Embrapa Genetic Resources and Biotechnology; Professor at University of Brasilia; and Member of the Brazilian Academy of Sciences (ABC).

3. Senior Researcher at Embrapa, Coordinator of Embrapa Labex-USA.

4. Senior Researcher at Embrapa, and Senior Advisor to Embrapa's CEO.

diverse climate regimes (from tropical to subtropical), combined with this natural capital, have created six biomes ranging from semi-arid to the Amazon rainforest. Brazil also has enormous biodiversity: nearly 60,000 of the world's 250,000 species of higher plants are native to Brazil (Lopes, 2012).

In 2014, Brazi had a total of 203.2 million people (IBGE, 2016b), with approximately 85% living in urban areas (IBGE, 2011). The workforce in the country totaled 98.1 million people in 2014, of which 13.9 million were enrolled in the agricultural sector (IBGE, 2016b). In the Brazilian economy, 32.9% of the workers were illiterate or had an incomplete elementary school degree, compared to a shocking 74.2% of workers in the agricultural sector who were illiterate or had failed to complete elementary school. The share of college-educated people also sharply contrasted with workers and those engaged in the agricultural sector: 14.3% of the total workers in Brazil had a bachelor degree compared to only 1.6% of workers in agriculture – which nonetheless is much higher than the 0.5% of college-educated workers engaged in agriculture in 2004 (IBGE, 2016b).

Brazil's agricultural value chains and contributions to UN's SDG #2

Over the past four decades, Brazil eventually became self-sufficient in food production and successfully improved the population's food security. In the recent past, the share of food secure population in Brazil increased from 60.1%, in 2004, to 74.2%, in 2013. During this period, the share of the population experiencing severe food insecurity decreased by a significant 8.7% per year, plummeting from 15% of the Brazilian population, in 2004, to 7.2% of the 2013 population (IBGE, 2016c).

This outstanding achievement reflected the fact that food production increased at a higher rate than food demand and, consequently, real food prices for consumers have significantly decreased in the past four decades. Currently, consumers pay roughly half the amount for a food basket than they did in the 1970s (**Figure 1**). Given Brazil's central role in world agriculture, this achievement undoubtedly contributed to global food security, one of the outstanding "United Nations' Sustainable Development Goals".

Furthermore, the fact that aggregated Brazilian agricultural production grew predominantly through yield increases, instead of area expansion (**Figure 2**) has decisively contributed to the generation of impressive land-saving effects that have enabled millions of hectares to be free from cultivation in the past 60 years. Thus Brazilian agriculture has not only become more competitive over the past 40 years, but has become more resilient and sustainable through the lens of sustainability (Martha & Alves, 2017).

Brazil's challenges in food and nutrition security

The future will pose challenges for sustaining the country's food security achievements over the past 15 years. During this period, Brazil effectively reduced poverty among its citizens. Whereas 9.4% of the population was below the $1.25 USD extreme-poverty line, in 2004, this share sharply decreased to 3.1% in 2014. The share of the population below the $3.10 USD poverty line was 24.9% and 8.5% for 2004 and 2014 (Osorio, 2014). Both extreme poverty and poverty were reduced by over 10% per year, reflecting the economic growth of the period.

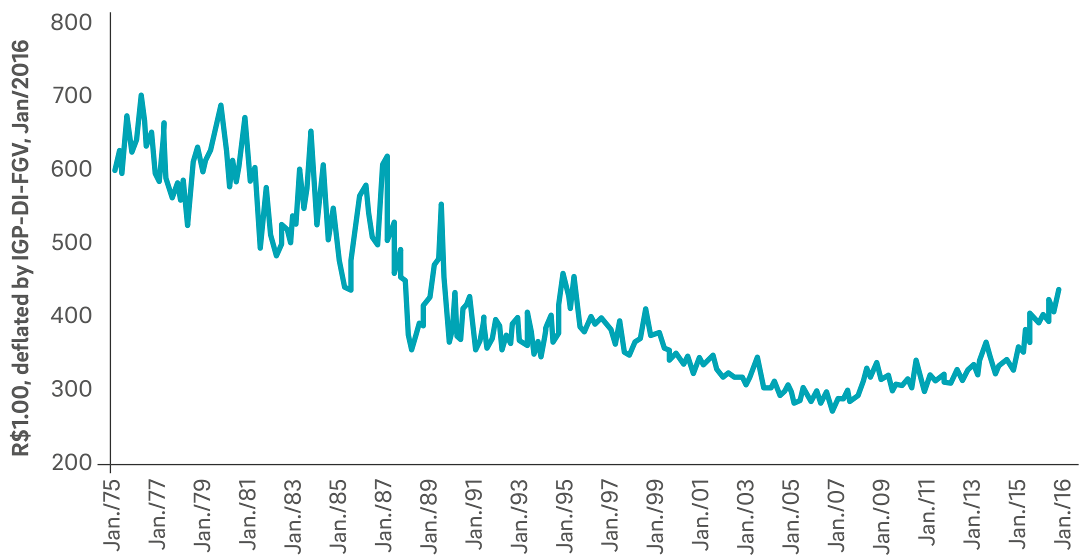
Economic growth is not everything, but it is certainly a key element in sustained food and nutrition security. Based on the World Bank's GDP per capita (PPP, constant 2011 international dollar) database, in 2004-2014, average per capita income increased by 2.4% in Brazil, from $11,968 to $15,162. However, after a peak of $15,281, in 2013, per capita GDP in Brazil decreased at a rate of 2.7% per year, to $14,454, in 2015. The economic situation measured in terms of per capita GDP deteriorated in 2016, as Brazil's GDP continued to shrink, making it difficult to maintain the food security achievements of previous decades.

To a certain extent, these economic pressures could be relieved if agricultural production maintained the rate of the past 40 years during which it consistently increased the agricultural output available to the Brazilian population at a higher rate than food demand (Martha &

Alves, 2017). The resulting income-effect of demand could benefit the Brazilian population, especially the poorest sectors, and decisively contribute to the country's food and nutrition security goals.

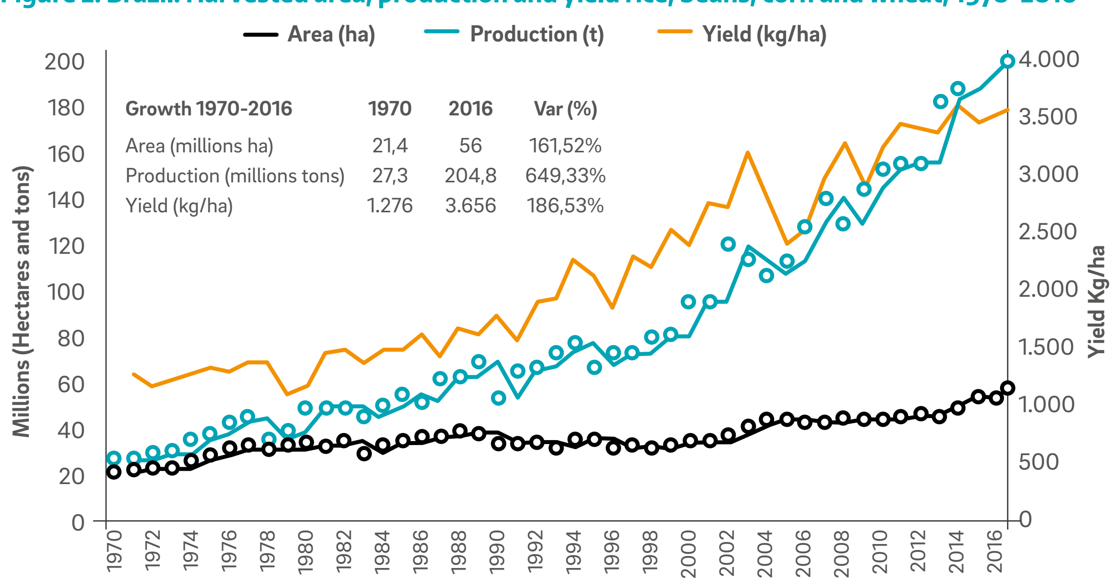
However, knowledge and technology will only be adopted on a large scale if a minimal level of reading and math skills is achieved. For example, at the farm level, modern inputs (seeds, fertilizers, pesticides, etc.) cannot be properly calculated, nor can machinery and equipment can be adequately adjusted for operation, without minimal knowledge of math and reading/interpretation skills to use the instructions manual. At a higher training level focusing on decision-making, basic theoretical knowledge, the use of scientific methods are eventually required (Rodríguez et al., 2008)

Figure 1. Real Prices of staple food for the city of Sao Paulo, Brazil (R$ 1.00)



Source: Diese. Reference Source Embrapa/SGL

Figure 2. Brazil: Harvested area, production and yield rice, beans, corn and wheat, 1970-2016



Source: IBGE. Reference source Embrapa/SNE to depart from the generally-accepted "rule of thumb" and make the necessary adaptations to the local production system.

The generation of knowledge and technology to address the future challenges of Brazilian agriculture and food security is a very clear goal to be pursued. Increasing investment in agricultural research and development is a decisive step toward that end. Furthermore, strengthening human capital at different levels is required for a more inclusive approach and to avoid any long-term restrictions on achieving higher technological agricultural production in the future.

2. Institutional Setting

Maurício A. Lopes,[5] Geraldo B. Martha Jr., Evaldo F. Vilela

Science-based Agriculture in Brazil

A virtuous cycle that expanded and strengthened tropical agricultural research began in Brazil in the 1970s. The government's commitment to supporting science-based agriculture was positively received by society. The private sector promptly adopted new knowledge and technologies to boost agricultural production. The sharp drop in food prices over the past four decades, along with associated lower price volatility, in addition to providing food security to Brazilian population, also contributed to alleviating inflationary pressures.

Technology generation and adoption in Brazilian agriculture has been a continuous process. Currently, technology already explains 68% of the agricultural product (Alves et al., 2013). In the future, the "technology-dependence" of agricultural value-chains is expected to increase to even higher levels and these "science for innovation approaches" must design alternatives for "real-world" challenges and opportunities (Embrapa, 2014).

5. President and Senior Researcher of Embrapa, Brasília.

Institutional Development. Research and Development (R&D) Organizations

Brazil improved its research structure and capacity substantially by developing a two-tier system of federal and state-based agencies, called the "National Agricultural Research System (SNPA) (Lopes, 2012). Over the decades, the SNPA (**Figure 3**) has been responsible for designing, implementing, developing and promoting a wide array of knowledge and technologies to contribute to innovation in agricultural value chains. SNPA includes State agricultural research organizations, universities (agricultural colleges) and Embrapa.

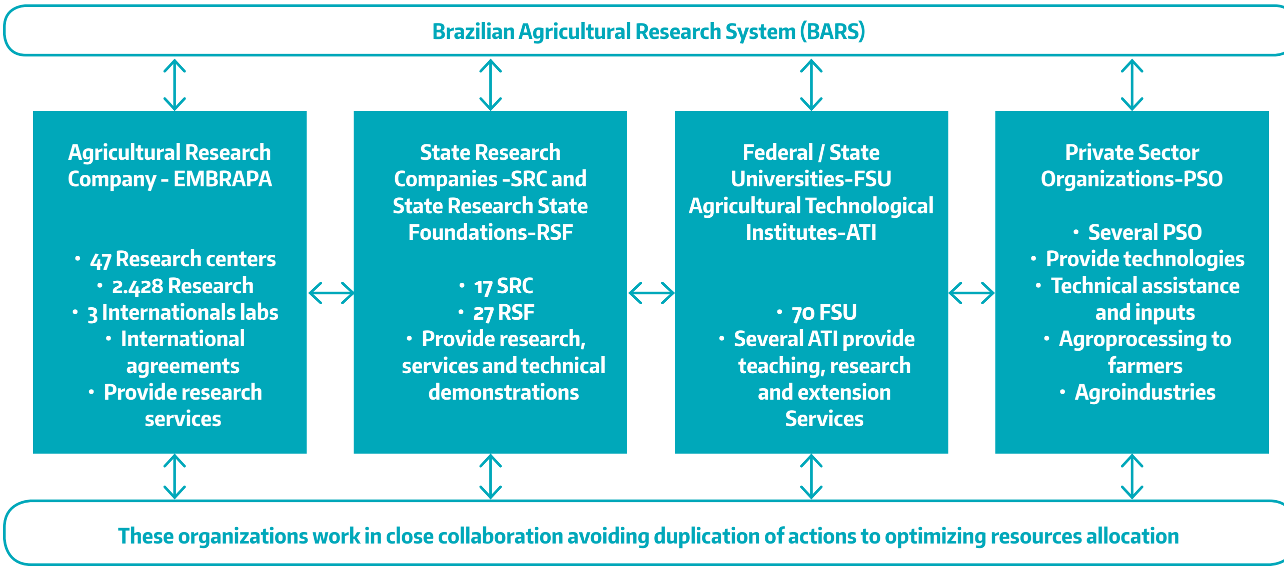
Embrapa was founded in 1973, with the aim of serving as the "research arm" of the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA). The model conceived by Embrapa is centered on capacity building and on excellence research centers. To facilitate interaction with farmers and society, the model chosen was an agency with a nation-wide mandate, decentralized in the territorial dimension and organized as centers researching products, resources and themes. Several State Governments also established their own agricultural research organizations in the 1970s and 1980s and Embrapa was assigned the additional mission of coordinating SNPA.

The Brazilian Agricultural Research System (**Figure 3**) led by Embrapa became one of the largest agricultural research networks in the tropical world. In 2013, Embrapa represented 42% of SNPA's research capacity, followed by the State Research Organizations (29%), Agricultural Colleges (26%) and non-profit organizations (3%). Full-Time research Equivalents in 2013 (FTE – 5,869.4) consisted of 72.5% of researchers with doctoral degrees, 21.5% with master degrees, and 6.0% with bachelor degrees. Nearly 60% of those researchers were concentrated in the 41-60-year cohort (Flaherty et al., 2016).

The Role of Human Capital

A major determinant in the successful development of Brazilian agriculture was the development and strengthening of human capital, in which education played a pivotal

Figure 3. Organization of the Brazilian Agricultural Research System (BARS)



Source: Prepared by the Author.

role. However, as discussed by Sowell (2015), education is important, but it may not be a reliable proxy for human capital, since human capital also demands the development of marketable skills and knowledge that directly affects economic outcomes. Human capital is increasingly in demand in an economy that is becoming both technologically and organizationally more complex (Sowell, 2015), such as agriculture and its value chain.

Embrapa is a good example of persistent investment in human capital and its pay-off. Since Embrapa's inception in the early 1970s, over a thousand of its employees have been sent abroad to be trained at the world's finest agricultural colleges. This strategy also helped stimulate creativity and establish an environment that encouraged coexistence and interaction among peers and different stakeholders. The basic idea is that Embrapa will always be prepared to capture, interpret and internalize the signals from a complex society as well as the international market, since the need for interaction across national borders will increase (Alves, 2010; Martha Jr. et al., 2012). Typically, Embrapa has shown a benefit/cost ratio for society's investment ranging from 8:1-12:1 over the years.

The Role of Brazilian Universities in the Development of Tropical Agriculture

Beginning in the 1960s, the development of the current Sustainable Tropical Agriculture was marked by the contribution of Brazilian universities focusing on Agricultural Sciences, which led to the implementation of specialized graduate courses in the country.

Inspired by the American "Land-Grant Colleges", the Federal Universities of Viçosa (UFV), and Lavras (UFLA) and the Luiz de Queiroz College of Agriculture (University of São Paulo), among others, have been making a major, contribution to the development of the Brazilian agricultural sector. This has taken place through a partnership with EMBRAPA, via the "Brazilian Agricultural Research System" comprising several research networks established with other universities and institutions in the country and abroad. These universities, which rank high in evaluations of Latin-American and global universities, have always undertaken basic and applied research, to meet the technological demands of the production of vegetable and animal products under local soil and weather conditions. They have gained renown for creating research environments that are relevant to the social and economic advancement of the country.

Over the past three decades, in the State of São Paulo alone, investments in agriculture and livestock farming research amounted to an annual average of 417 million Brazilian Reais, including federal resources, with special attention being paid to research on sugar cane and beef and dairy cattle. During the same period, an average of 415 million Brazilian Reais (R$3.15/US$1.00) was invested in higher education in the agriculture field, most of it allocated to USP, UNICAMP and UNESP. The return on public investments in human capital is comparable to the results obtained in the US, where each dollar invested generates up to $13 USD in revenue.

The teaching-research-extension trilogy, inherited by Brazilian agricultural universities from the cooperation with the American Land-Grant Colleges, greatly favored the training of professionals in higher education, especially in master -and doctoral- degree programs to work in the agriculture sector.

Brazilian universities are directly responsible for the significant growth of scientific production in various fields of knowledge in the country, since they concentrate the largest number of Ph.D.'s and most of the research infrastructure. Over the past 20 years, the number of articles published per million inhabitants in the country grew from approximately 20 to 182, above the world average of 170 articles per million inhabitants, and agricultural sciences made an unquestionable contribution to this progress.

In 2016, agricultural sciences accounted for 270 graduate programs in Brazil, including 204 traditional master-degree programs, 46 Ph.D. programs and 20 professional master programs. The number of doctoral students graduating from Brazilian universities grew by 486% between 1996 and 2014. In 2014, 50,200 master and 16,700 doctoral students, including those in the agricultural sciences graduated from the country's universities.

Concluding Remarks

Enormous challenges still lie ahead. The future of Brazilian agriculture will eventually be shaped by multifunctional concepts, methods and applications far beyond the current conventional views of agriculture as a system dedicated to the production of food, feed, fiber, feedstock, energy and environmental services. Innovations in R&D organizations and collaboration networks will need to correctly interpret future needs and evolve accordingly.

Over the past four decades, agricultural research in Brazil has relied on the Brazilian Agricultural Research System. A broader, more comprehensive alliance is now being considered under the auspices of the Brazilian Ministry of Agriculture, Livestock, and Food Supply. This Alliance for Agricultural Innovation in Brazil seeks to reinforce the multi-institutional environment, so that research and innovation processes will be further strengthened to better accommodate the articulation, alignment and synergy between the actors involved in the research and innovation processes. This approach should generate an innovative dynamic capable of attracting new public and private funding sources and leverage the knowledge generated by agricultural research, adding more value to the entire value chain.

It is worth noting that the ability of technologies to foster agricultural competitiveness is not only limited by scientific knowledge, but also by non-technological factors. Bottlenecks in logistics, storage and transport infrastructure, the availability and cost of energy, among other factors, may work as headwinds to technology adoption.

Last, but certainly not least, increasing production through more efficient use of resources will necessarily entail greater investment in human capital. Furthermore, it should be noted that no organization or even country has all the solutions needed to fully and adequately respond to the challenges and opportunities ahead. This means that Brazilian agricultural R&D Organizations must strengthen partnerships and alliances within and beyond the country's borders. Enhancing cooperation will therefore be essential to establishing a sustainable path for agricultural value chains and the emerging bio-economy.

3. Resources and Ecosystem Characteristics: Plant Production, Genetics and Biodiversity

Élcio Perpétuo Guimarães[6]

Introduction

Glancing through various documents on global issues such as food security, sustainability, climate change effects and biofuels shows that Brazil is part of the problem, but also part of the solution. There is no doubt in people's minds that this country is the world's food basket and a place where lessons can be learned. Brazil's agricultural production grew exponentially in recent decades, mainly due to the application of research results and technology. Nevertheless, there are negative factors associated with it, such as the overexploitation of natural resources and excessive use of agrochemicals (Brazil is currently the world's largest user of agrochemicals).

The latest statistics on Brazilian grain production show another record: total grain production in 2016-17 exceeded 227.9 million metric tons, with soybeans accounting for the largest amount, with 110.1 million tons, followed by maize with 91.5 million and rice with 11.9 million (Conab, 2017). It is impossible to talk about food production in the country without mentioning how Brazil improved its resource and ecosystem management. FAO 2006 data show that from 1975 to 2005, the area-under-cultivation declined by 1.91% (from 695 to 681.7 million hectares) while productivity grew by 84.7% (from 1.76 to 3.26 thousand/hectare). Again, the main driving force to obtain these results was the use of science and technology.

The major challenge for the country in the coming decades is to sustain growth with a minimal expansion of the area-under- cultivation and maximal productivity increases. The role of science and technology is to produce innovations that will enable the country to produce more in a sustainable manner, increase nutritional quality, and respect the environment more and its various biomes (**Map 1**); all in a world increasingly affected by climate changes we do not yet fully understand.

Plant production

Going back in history, we see that the continuous increase in productivity was the key element that enabled societies to flourish. In the beginning, hunters needed 2,500 hectares to feed one person; in Egyptian agriculture 10% of this area fed 750 people, whereas in today's agriculture that same 10% feeds 3,600 people (Paterniani, 2001).

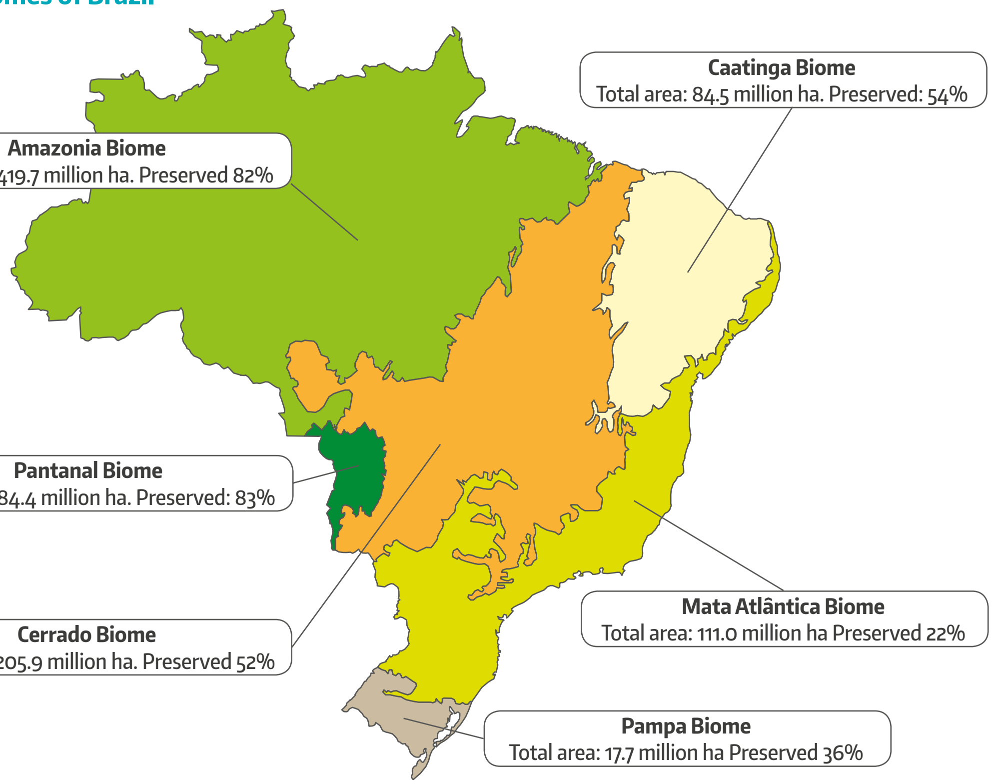
In the 60s and 70s, the aim was to cultivate one crop a year and to achieve the highest possible production. To achieve this, high fertilization levels were used generally in combination with overexploitation of natural resources. As time went by researchers developed more complex agricultural systems, achieving year-round land use. In these systems, crops are integrated with livestock, and in some cases the forest is also incorporated (Balbino et al., 2012). Farmers also came up with creative responses to increase and sustain food production, such as the zero-till system, which exerted an impact on the whole country. In general, the increase in complexity was not only associated with an increase in production, but finding more sustainable ways to run agricultural and livestock systems.

The land-use change caused by the expansion of livestock and agriculture posed a series of challenges for research, the main one being the lack of sustainability due to pasture degradation and monocropping (Aidar and Kluthcouski, 2003), which are still waiting for better answers from science. In general, these challenges linked to the sustainability of production systems are not related to the static view where systems are considered sustainable when production is kept at the same level, but to the dynamic view where systems evolve to adjust to society's demands.

The intensification, integration and increased complexity of the agricultural production system brought problems of pests, such as the white fly, which is currently a major problem in common

6. Senior Researcher at Embrapa Rice and Beans, Goiania, Goias, Brazil. Email: elcio.guimaraes@embrapa.br

Map 1. Biomes of Brazil



Source: Projeto Biomas (CNA/Embrapa); MMA.

beans, but also affects soybeans and other crops, forcing farmers to constantly use chemicals. The continuous exploitation of the soil's chemical and physical capacity is also a major issue. The challenge for research is to understand how to balance complex systems in such a way that extraction is neutralized by the addition of chemical elements, without entailing high costs for farmers or the environment. A major issue involves keeping and improving the soil's organic matter (Neufeldt et al., 2002). In the Cerrado ecosystem, a major limitation for sustainability is the low levels of organic matter in the soils. Accordingly, research designed to increase and sustain the organic matter in soil must have a high priority. This is also true for other ecosystems, such as Caatinga for example.

On the subject of Caatinga, water use efficiency is a challenge in the Northeast (NE), where sugar cane and fruit production are major components of the production systems and water shortage has become a major issue. This is also true for rice production in South and Central Brazil. Despite the importance of these production regions for the country and the severity of water shortages, science has not yet been able to understand this complexity and come up with solutions that not only protect the ecosystem, but also help farmers increase productivity. The development of varieties that use water efficiently and water-saving technology are key elements for consideration.

Looking at the country as a whole, agriculture and livestock changed Brazil from a food-insecure country to a major food exporter in a few decades, in addition to accounting for a quarter of its Net Domestic Product (NDP). This production comes from various ecosystems (**Map 1**), which have been contributing to the nation's production in different ways. The Cerrado ecosystem developed exponentially and in less than five decades became the largest agricultural production area in the country. The major challenges here are related to infrastructure and logistics, but science is still struggling with the development of intensified and sustainable systems. No-till farming was a step in the right direction, but the prevalence of commodity crops such as soybean and maize, is still a major topic. Developing intensive, sustainable production systems is the main issue here. In the Southern region of Brazil, where agriculture has a longer history, sustainability and intensification of production systems are also major challenges. In the Caatinga region, water enabled farmers to become market-oriented, whereas in the past, the major focus was on family production. The development of irrigation systems enabled the production of commercial crops and diversification from cassava to sugar cane and fruit. Water-use efficiency is undoubtedly the main area for research. There is a need to invest in varieties that are more tolerant to water stress and in more efficient irrigation systems. The Amazon ecosystem has very particular characteristics meaning in the long run, agriculture has a less important role to play than the exploitation of local and native species. Extensive livestock and soybean production in deforested areas are currently major contributors to production. As with other ecosystems, sustainability is the main issue, while the development of integrated production systems is the main challenge.

Science is moving swiftly in the direction of offering tools to farmers to understand the behavior of their production systems, in all ecosystems, in real time, by integrating crop behavior with soil and water conditions. Today, drones fly over farms to obtain information on where and how interventions are needed to prevent crops from diseases and insects (Fonarce et al., 2014).

These data are analyzed and computers provide information on better ways to manage the problem. Machines tell us where, how and how much fertilizer to apply considering the soil characteristics, making precision agriculture part of farmers' lives. Automation is contributing to better management of the production system and allows more complex systems to be productive and sustainable. All these innovations are already part of Brazil's agricultural systems. However, looking ahead, Brazilian agriculture is not only expected to focus on producing more and better food, feed, fiber and fuel, but also to contribute to climate change mitigation, while minimizing environmental impact.

Genetics

In today's world, the responsibility for feeding its population lies in the area of genetics. Its contribution is not only linked to food production but also to fiber, feed and fuel. Since the inception of genetics, breeders have been using this knowledge to develop improved varieties on an annual basis. They have been seeking methods and tools to allow them to make specific changes in the genome and increase their efficiency in producing better varieties.

Before talking about today's new opportunities, it is noteworthy that the application of Mendel's laws allowed us to increase productivity exponentially, mainly for the major crops. It also made it possible to develop varieties that are more resistant to diseases and insects, and more tolerant to abiotic stresses. However, the complexity of today's cropping systems and the need for faster, better responses to the limiting factors are posing additional challenges for breeders.

Recently, as a result of the advances in life sciences, this challenge seems to have been overcome and genetic modifications have set new boundaries to breeding. Today, discussions about synthesizing a human genome continue to be held. In 2010, the creation of artificial life was reported, in the US, by the J. Craig Venter Institute (JCVI) (Gibson et al., 2010), which gives us an idea of how fast the field is advancing. Going back to the last century, we all remember the advent of transgenesis and how it drew the world's attention to how gene manipulation techniques could offer alternatives for improving crops' capacity to resist pests, but also how a technique could be an element for contributing opinions to different and extreme positions in the use of science to support agriculture.

Transgenic crops resistant to herbicides and insects achieved savings in chemical applications and effectively contribute to better environmental management. In the near future, science will do more, yet without the polemics related to transgenic technology.

Life science technology is developing extremely quickly. In 2003, when the human genome was completed, the estimated cost was nearly $4 billion USD and the entire project took ten years. Today there are companies inviting you to have your genome sequenced for approximately one thousand dollars in a single afternoon.

The genome-editing tool called CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology will revolutionize the way breeding is done. The technology is based on enzymes, which work like molecular scissors, cutting and inserting genes into an organism in a controlled way (Cong et al., 2013). This makes it possible to develop new varieties targeting new genes for resistance and tolerance to environmental stresses, such as drought, flooding, cold and heat, and improved nutritional contents.

Despite these advances in genetics and opportunities to improve the use of resources and ecosystem characteristics, Brazil is still struggling with the basics. A glance at the number of public breeders and institutions working with plant breeding in the country shows that these numbers are not increasing and that in many cases, they are declining; fortunately, private breeding is flourishing (Geraldi, 2012). However, this growth has been observed in commodity crops, such as soybean and maize, whereas for non-commodity crops there are fewer experts and investments (Ramalho et al., 2010). Cassavas and beans, for example,need more attention and investment, which must come from the public sector.

The increase in environmental changes requires a better understanding of our resources and ecosystems characteristics, which brings us to the next topic: the need for better conservation and use of the country's biodiversity. The application of genetic tools to manipulate plants becomes a high priority, but since the problems are more complex, more complex scientific teams will therefore be required. The challenge is to form teams of experts to solve problems; it is necessary to combine breeders with physiologists, geneticists, biotechnologists, entomologists and pathologists, all working together and focusing on how to manage the resources in the various ecosystems better.

Genetics has developed exponentially, private investments in important commercial crops also grew significantly, and it is now up to us to make the case for increasing investment in food security crops and crops that are important for farmers not in the major leagues.

Biodiversity

Biodiversity can be defined as the total amount of genes, species and ecosystems in a given area, region, country or even the world. The concept of biodiversity refers to three areas: the first related to the diversity among species; the second linked to the variability within species or genetic variability, which is the building block for breeding programs, and the third associated with ecosystems.

In 1992, in Rio de Janeiro, Brazil, representatives from over 150 countries signed the Convention of Biological Diversity (CBD), an agreement that expresses concerns related to genetic diversity losses worldwide and the need to join efforts and resources to prevent these losses. It is commonly understood that there is no single country self-sufficient in plant genetic resources (Convention on Biological Diversity, 1992).

The logical question to ask is, "Why are these losses a concern". The short answer to this question is, "Biodiversity is fundamental for providing ecosystem services", which in turn is essential for human well-being. Biodiversity is responsible for food security, health, clean water and energy production.

In February 2008, the Norwegian Government opened the world's largest seed-storage security facility "The Svalbard Global Seed Vault", designed to ensure against seed losses in other genebanks during regional or global crises (Fowler, 2016). This initiative was proposed with the aim of preserving the world's plant genetic diversity.

Brazil is among the most diverse countries in the world. Brazilian flora is the most diverse with approximately 55,000 species accounting for a quarter of the of the world's total number of species. The country's Cerrado, Atlantic Forest, and Amazon ecosystems are the richest plant bioms on earth. This biodiversity must be used for it to have significance for the country and the world; preservation must be a priority, but rational use must be part of national development strategies.

Brazil has been taking advantage of native and exotic genetic diversity to improve its main crops and provide choices for farmers to adapt to ecosystem changes. Even though breeders tend to focus on improved materials to maintain their breeding programs, native or wild genetic resources are crucial to national breeding strategies since they provide opportunities for new genes to be part of the genetic pools managed by breeders and solutions to cope with current and potential limitations (preventive breeding).

Despite the current legislation, which does not encourage the use of national wild genetic resources, breeders are still taking advantage of opportunities and using local diversity. The main crops where Brazil has wild relatives present in the different biomasses are Arachis, Manihot, Anacardium, Hevea, Oryza, Ipomoea, Solamun and several tropical fruits such as passion fruit. An additional challenge to breeding programs is that in practical terms, national legislation does not encourage the exchange of genetic resources with other countries, hampering the advance of those programs.

In recent decades, taking advantage of biotechnological tools, assessment of genetic diversity through molecular markers was undertaken for almost all relevant crops worldwide. These studies showed how to develop conservation strategies and more importantly, provided a better understanding of how to use this genetic diversity to develop improved varieties.

In addition to the previously mentioned benefits, diversity is also valuable for tourism. In Brazil, the exploitation of diversity as a source of income related to tourism is limited and concentrated in the South of Brazil, where the wine circuit is a good example. However, interest in this type of tourism is expanding worldwide and in Brazil, efforts should be made to leverage its enormous biodiversity. Only 10% of Brazilian flora and fauna have been described and registered (25% of the world's known plant species are found in Brazil).

Biodiversity is crucial for Brazil to continue its pathway in agricultural growth. Therefore, more flexibility and speed to exchange genetic resources are required for the country to be respected in the international arena. It is also essential to implement better strategies to collect, conserve and use genetic resources.

4. Technology and Innovation

Geraldo B. Martha Jr., Elibio Rech, Mauricio A. Lopes, Evaldo F. Vilela, Paulo Renato Cabral,[7] Cleber Oliveira Soares and Grácia Maria Soares Rosinha[8]

Brazilian agriculture and technology

The development of Brazilian agriculture over the past four decades and its positive outcomes in terms of competitiveness and sustainability have been widely recognized as a success story (Economist, 2010; Pereira et al., 2012). By and large, technology generation and adoption were key drivers in the modernization of Brazilian agriculture (Martha & Alves, 2017). Despite such progress, it is essential to advance even further along the sustainability path and to solve localized drawbacks in agricultural production (Fedoroff, 2015), and environmental and social claims (Rech & Lopes, 2012; Erb et al., 2016). It is also necessary to recognize and support "science for innovation approaches" to design feasible alternatives for "real-world" challenges and opportunities in the future.

Brazil has an abundant supply of natural resources, which have been largely protected by the enormous land-saving effects, resulting from the productivity gains in Brazilian agriculture in the past decades. An obvious key issue for the future of agriculture in Brazil is to improve the understanding of the country's biodiversity and biome characteristics and functioning (Rech & Arber, 2013), and efficiently incorporate this knowledge into agricultural systems to achieve greater production with increasing resilience and

7. President of the Institute for Innovation. Brazil.

8. Senior Researcher at Embrapa Beef Cattle. Brazil.

sustainability. Through this approach, strategies to improve ecosystems services could be better designed, and society's overall well-being will be improved while at the same time maintaining high levels of protection of Brazilian biomes. Since human perceptions and choices ultimately determine polices, decisions and courses of action they cannot be disregarded.

Broadly speaking, two major approaches in technology development can be identified: land-saving and labor-saving technologies. In the former case, biochemical advances are central, whereas mechanical technologies will be key in the latter situation. Outputs in both cases will eventually be influenced by people's ability to understand and successfully implement novel methods, tools and courses of action in a desirable direction and in a timely manner.

Land-saving technologies

Agricultural production is the result of increased area and/or increased productivity. Generally, a combination of both factors explains observable production levels over time. A key issue for future agriculture will be to promote land-saving technologies, since these approaches can greatly increase agricultural output without the need to increase the area-under-cultivation. Understanding the extent to which the rate of yield gain can be accelerated and effectively implemented by farmers, to achieve greater production, is nonetheless essential.

However, remarkable scientific advances are taking place in various fields of knowledge. Genetics typically represents as much as 40% to 50% of the contribution to yield increases in agriculture (the remainder being achieved by fertilizers and other chemicals). Therefore, many important biological functions explored through modern biotechnology can be gradually incorporated into agricultural value chains.

Great progress has already been made in genomics, cell functioning and bio-informatics. Indeed, recent advances reflect the consolidation of modern biotechnology, in genetic engineering, genomics through integrated genetic improvement by metabolic engineering, advanced reproductive technologies and animal cloning. These advances, in turn, have the potential to transform markets and increase the possibilities of developing and consolidating a dynamic bio-economy in the country (Embrapa, 2014).

Synthetic biology (Medford & Prasar, 2016; Nielsen et al., 2016), a result of the convergence of the digital world and the biological world, will pave the way for an unusual range of biopharmaceuticals, bio-inputs and bio-products (Martin et al., 2003; Rech & Arber, 2013). The new technology of genome editing called CRISPR-Cas9[9] (Zhang et. al, 2013) will have a paradigm-breaking effect on plant research, genetic engineering and crop breeding and promises to revolutionize the science of genetic modification. This technique will soon make it possible to edit genomes just as one edits a text, by removing or modifying parts of the DNA of the plant itself to modulate desirable traits.

From an agricultural systems perspective, Brazilian agriculture is dependent on imported materials and/or products derived from non-renewable sources. Fertilizers and crop protection inputs (together with improved agricultural practices) have transformed agriculture in the tropics. Nevertheless, these inputs may represent as much as 50% of production costs. Biological Nitrogen Fixation (BNF), which fixes nitrogen from the atmosphere and makes it available for plant production, as well as other "bio-input approaches", could translate into positive economic results for farmers and agricultural value chains, with fewer negative impacts on the surrounding environment.

Labor-saving approaches

Demographic trends including an aging population and sustained migration from rural areas to the cities have been identified (UNPD, 2015). Labor in agriculture is, thus, expected to become increasingly scarce. Insufficient schooling years and technical training limit laborers' ability to deal with more complex technologies and will further exacerbate labor scarcity in rural areas.

9. "CRISPR stands for Clustered regularly-interspaced short palindromic repeats, and represent segments of bacterial DNA that, when paired with a specific guide protein, such as CAS-9 (e.g., CRISPR-associated protein 9), can be used to make target cuts in an organism genome" (Collins et al., 2016).

These signals clearly reflect the increased demand for automation, mechanical technologies and robots in agricultural value chains to better manage the labor shortage and pressure on salaries, positively contributing to labor-productivity growth. The advancement of Big Data and precision agriculture (or site-specific management systems) will not only require novel mechanical/automation technologies, but also demand intensive and sophisticated managerial innovations in Informations and Communications Technologies (ICT).

Climate change, bio-economy and non-technological factors

Enormous challenges still lie ahead as agriculture is simultaneously forced to focus on competitiveness and sustainability. Climate change, for instance, affects agricultural value chains and may place pressure on all its components, e.g., from natural resources, to farm and industrial production and competitiveness, and ultimately to consumers.

In the long run, climate change impacts on Brazilian agriculture are expected to translate into a complex spatial dynamics of reduction and expansion of agricultural areas, in a challenging (and unpredictable) production environment. In this context, strengthening research and innovation systems is essential to allow technological progress to advance at least at the equivalent rate at which the climate imposes negative changes on the production environment. In this scenario, negative consequences could be avoided, or at least kept at acceptable levels (Embrapa, 2014). More research is needed to mitigate the effects of extreme weather events, increase systems' resilience and allow adaptation to new scenarios of heightened biotic and abiotic stress, as well as energy insecurity.

The future, however, also promises enormous opportunities for strengthening comparative advantages, income generation and job possibilities in Brazilian agricultural value chains. Bio-economy is a good example. The broad variety of biomass (such as sugar cane, sweet sorghum, tropical fodder palm-trees and co-products) offers real opportunities for the development of value chains based on high value-added materials and substances targeted for food, feed, flavors and non-food uses (chemical and biochemical, medical and pharmaceutical, nutritional and energy). Chemical-bio-catalytic processes lead to the development and use of microbial catalysts that directly convert raw materials into a range of products and chemical intermediates which, in turn, can be subsequently converted into new products with high value-added potential (Embrapa, 2014).

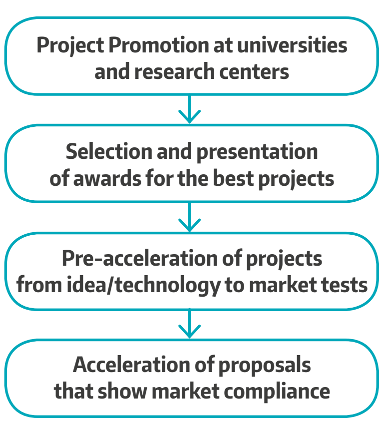
Fostering a bio-economy strategy in the country would eventually boost the growth of associated capital-goods industries, engineering services and biomass suppliers in food, feed, chemistry and pharmaceutical value chains, and create opportunities for expanding higher value-added exports. Both the search for greater efficiency and production linkages in well-known sectoral dimensions, as well as the search for novel biodiversity uses, in order to deliver innovative products and processes, associated with increased productivity and higher-quality jobs, should be pursued (Embrapa, 2014).

It is also important to realize that the ability of technologies to foster agriculture competitiveness is not only limited by scientific knowledge, but also by non-technological factors. Bottlenecks in logistics, storage and transport infrastructure, availability and cost of energy, among other factors, may act as severe headwinds to technology adoption.

The Role of Youth Innovation for Sustainable Food Production

Brazilian research increasingly takes place within a network, which has encouraged multi-disciplinarity and made it possible to break down the barriers that previously isolated subjects. Today, robotics and agriculture work together, as do computing and microbiology and other fields. In turn, the gap between universities and industry is narrowing due to a growing startup movement. Small companies created by students and their mentors, motivated by dreams of starting their own businesses, have been turning the results of doctoral research projects and their patents into business. This is a new technology-transfer model that brings knowledge generated by research to the market. Faster and less costly, it makes patents created through projects into a reality, fast-tracking innovative products and processes. Startup culture has the ability to solve market problems, encouraging projects to incorporate a market focus into their methodologies, which may involve a challenge or a problem that affects agriculture activities or its producers.

In this context, the Youth for Sustainable Food Award, a strategic initiative for the Forum for the Future Institute, seeks to align the perspective of young talents in Brazilian universities and their entrepreneurial capabilities, in a scenario of opportunities created by the need to increase the production, productivity and nutrition effects of grains, fruit, meat and other food products. The Youth for Sustainable Food Award is a cornerstone for the discovery of new talents which, once nurtured and monitored, will be able to generate technological solutions, as well as small companies with enormous potential for the agricultural and livestock system. The World Bank's decision to expand The Youth for Sustainable Food Award from Brazil to the whole of Americas reflects the Bank's effort to create opportunities at a critical moment for a region that needs to generate wealth. Through this strategy, the country will enable the materialization of ideas and technologies through the following process:



Following the selection and awarding process, the pre-acceleration stage, which includes market and management consulting, offers groups the opportunity find out about the value chain where the technology will be inserted, as well as the target market and the tests required for the implementation of technologies that will contribute to the production of sustainable food, from a food and nutrition security perspective. At the acceleration stage, projects that have demonstrated market compliance, that is, the technology and knowledge that have proven practical and feasible for implementation will be supported. Projects that have reached this stage will undergo tests to determine their market acceptability and technology prototyping with the final customers. The connection to the final-customer demands from the methodology and the ability to speak with agroindustries – producers and suppliers of agricultural supplements, seeds, fertilizers, vaccines, livestock feed and others – involves enormous coordination with R&D teams from companies that take an interest in innovation and the development of new business.

Through this strategy, recently graduated Ph.D. students, for example, will receive the necessary support to effectively bring the results of scientific and technologic research to society. Recent examples of successful startups in biological pest control, for example, include PROMIP (predatory mites) from ESALQ/USP (Faculty of Agronomy of the States University of São Paulo - Brazil), and RIZOFLORA (biological nematicide) from the Federal University of Viçosa. Both companies were recently sold to investors.

Animal Agriculture
The role of biotechnology

Research, Development and Innovation (R&D&I) have contributed to improving quality protocols from good agricultural practices to integrated production systems through traceability and certification. The target is to establish and enhance crop-livestock-forest integration technologies to develop future-bearing technologies (biotechnology, nanotechnology, genomics, proteomics, bioinformatics), provide tools for Information and Communications Technologies (ICT), advance precision livestock farming, explore energy efficiency in production systems, reduce GreenHouse Gas (GHG) emissions, reclaim pastures, and develop technologies for genetics, nutrition, animal health and farm management (Soares, 2014).

In this context, biotechnology has made an outstanding contribution and could continue to contribute to increase animal productivity in Brazil (**Figure 4**) through the increasing use of animal-breeding biotechnologies (traditional artificial insemination, artificial insemination at fixed times, embryo sexing, manipulation and transfer and animal cloning). It also will continue playing a role through the improved use of molecular marker panels for production phenotypes in beef and dairy cattle and the use of enzymes and microorganisms that improve ruminant and monogastric digestive efficiency, and the use of genomic selection associated with EDP (Expected Differences on Progeny), which accelerates the breeding and genetic improvement of livestock.

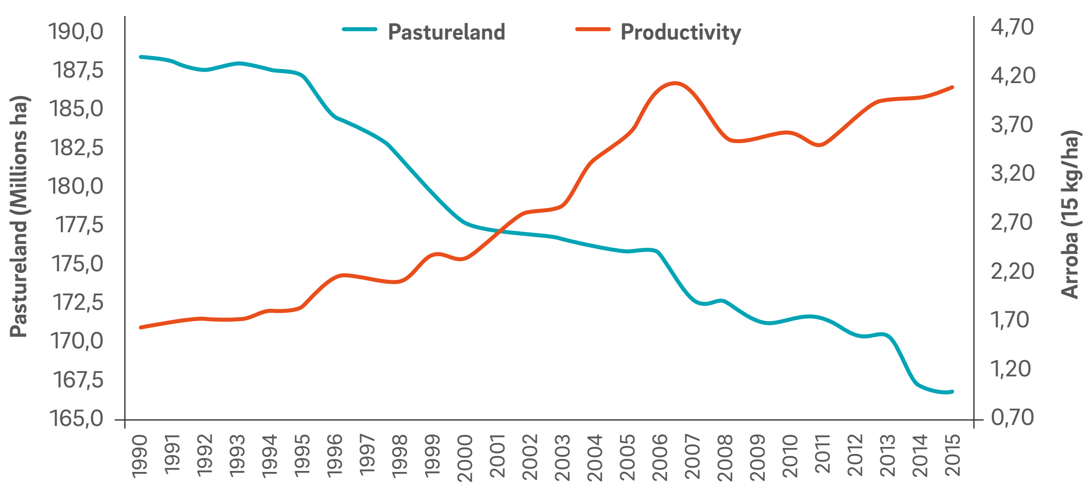
Pest and diseases

One of the major challenges for food security is preventive Veterinary Medicine to address the risk of biological pathogens, especially those that are easily dispersed as well as exotic ones. Moreover, the search for ante-mortem diagnostic methods, the development of inputs for prevention, surveillance and the control and treatment of diseases play a key role in food security, as well as in controlling the spread of diseases in production, biohazards and those leading to sanitary barriers. In this context, advanced biology, whether through biotechnology, or nanotechnology and bioinformatics has advanced greatly in Brazil, making effective contributions to animal production. Moreover, this process should be stressed in the future actions of Research&Development&Innovation (R&D&I), to ensure sustainable increases in yield and the agri-food production system.

Advanced biology techniques have been routinely used to develop materials and tools for animal health. Pathogens causing diseases that affect food value chains, such as viruses, bacteria and parasites, have been diagnosed, monitored and prevented using the most modern approaches in future-bearing sciences. New genes, proteins and other biological inputs (enzymes, carbohydrates, glycoproteins, amino acids, chimeras, etc.) of these and other strategic pathogens have been used for diagnostics and vaccines (Melo et al., 2015; Viale et al., 2016). Advances in these techniques must be capitalized by research organizations to stay ahead in the development of agricultural sciences.

A major contribution of these technologies has been mapping the resistance and susceptibility of animals to TSE, diseases with a high impact on the economy of countries producing animal protein since they are of great

Figure 4. Brazil: Pastureland vs Productivity of Beef Cattle, 1990-2015



Source: Agroconsult, based on IBGE and indicators.

concern to global food security, especially scrapie in sheep and goats and Bovine Spongiform Encephalopathy (BSE) in beef and dairy cattle. These tools not only help genetic selection, but also breeding programs, epidemiological risk analysis, prevention and programs of these and other diseases (Galvão et al., 2012; Gonçalves et al., 2016). This innovation is a great example of how biotechnology and innovation have helped ensure food and nutrition security in Brazil. Using these technologies has helped the country continue to be rated as having negligible risk for BSE from the World Organization for Animal Health (OIE, 2016). This ensures nutrition, health and the safety and quality of food for domestic consumption and export. The Brazilian agricultural research system will continue addressing the challenges to keep agricultural production increasing over time, by generating and adapting novel technologies to increase agricultural production in a sustainable way.

Prospects for novel agriculture products

Worldwide, the agricultural sector primary mission is to produce food, fiber and energy in a sustainable manner, without impacting biomes, striving for the conservation of biological and natural resources. This is the appeal of sustainable tropical agriculture. Within this approach, Brazilian R&D Organizations have been developing technologies and should continue along this path to food sustainable production, through integrated Crop-Livestock-Forest Systems (ICLFS), sustainable farming, the modern "Carbon-Neutral Brazilian Beef" concept, and other sustainable technologies.

These systems constitute innovations in Brazilian agriculture and are the pillars not only for increasing yields, with the aim of saving/optimizing land use while adding value to products, but also for mitigating Greenhouse Gas Emissions (GHG). They are therefore the most robust technologies for the future of sustainable agriculture in the tropics. Animal welfare is another highlight of Brazilian cattle systems. It makes it possible to reach and supply the most demanding consumer markets, which are interested in beef from grazing systems, also called "grass-fed beef" and "grass-fed milk" where it is crucial to turn an intangible feature (welfare) into a tangible one (final product quality). Research organizations must now address the challenge of mastering and generating innovative production systems to ensure food security domestically and abroad.

In this context, emphasis has been placed on multifunctional production systems such as ICLFS, which, in addition to helping reclaim low-yield degraded areas and pastureland, offer direct and indirect benefits to animals, such as providing shade and improving microclimate and local environmental conditions. These aspects have a positive impact on animal welfare and have become closely associated with prime end-products. According to the type of trees (native and exotic) and spatial arrangements (single, double or triple tree rows), there is a decrease of 2°C to 8°C in local temperatures within ICLFS systems, when compared with pastures without trees. As a direct result of the thermal comfort provided, there is improvement in productive and reproductive performances (Karvatte Jr. et al., 2016).

These concepts have contributed to the implementation of sustainable livestock-production systems, especially regarding environmental aspects, through the introduction of a forestry component, capable of neutralizing the methane emitted by cattle. This adds value to beef and other products generated in these systems. It also attempts to confirm the strategic importance of sustainability for associated supply chains (beef, grains and forestry), to promote the use of integrated systems, therefore optimizing the use of inputs and production factors, with positive effects. The "Carbon-Neutral Brazilian Beef" label is a trademark concept that certifies that a given beef load had its GHG emissions neutralized during the farming phase by cultivating trees under integrated silvopastoral (forestry-livestock) or agrosilvopastoral (crop-livestock-forestry) systems. The whole production process is parameterized, audited and certified. Therefore, research should continue attempting to obtain new labels for other products and adding value for agricultural production in worldwide markets.

Technologies such as these are realities in Brazilian cattle production systems, which together have created green cattle farming, a new revolution in the way sustainable beef, milk and their products are produced in the tropics, while contributing to a virtuous carbon cycle.

Other major challenges

The United Nations Organization called for Brazil together with the Southern Cone to supply 40% of world's food demand over the next few years. Sustainable increases of yields is a known alternative for increasing the world's food supply, without clearing new land. This is the basic concept to be further developed by the tropical sustainable-agriculture systems. In this regard, Brazilian private and public institutions have been tackling the challenge of developing sustainable farming practices such as integrated crop-livestock-forestry systems and the "Carbon-Neutral Brazilian Beef" initiative, among other emerging sustainable technologies.

Moreover, food safety throughout the beef production chain, ensuring improved health and nutritional standards, is another important challenge for ensuring food security worldwide. It is necessary to support future-bearing technologies, especially those related to biotechnology, nanotechnology, synthetic biology, and ICT, among other tools. Furthermore, agricultural sciences seek to develop cultivars, breeds and superior genetics for the large-scale production of fortified foods with improved nutritional quality and nutraceuticals.

5. Increasing Efficiency of Food Systems Chains

Antônio Márcio Buainain[10]

Introduction

Future demographic and economic scenarios indicate that the production chains of Brazilian agribusiness will be subjected to a great deal of pressure, and will have to address the two-fold challenge of quantity and quality. On the one hand, the system will have to produce agricultural products and raw materials in sufficient quantities to meet growing demand, while complying with the quality standards and characteristics required by markets and society in general. On the other hand, the increase of agricultural production will be contingent on a set of increasingly demanding and taxing restrictions and regulations posed by a new group of existing institutions, concerned with the competitiveness of global production chains, sustainable use of natural resources, social production relationships, preservation of biodiversity and equity (Buainain, 2014).

This new context implies radical changes in the growth pattern of agricultural production and in the dynamics of agribusiness production chains. Until recently, supply growth was based on two axes: the incorporation of new lands and technological innovation, with little concern for the sustainable use of natural resources - with the exception of the successful dissemination of direct planting techniques, which currently benefit over 33 million hectares (**Figure 5**) of areas-under-cultivation. Forests rich in hardwood and precious biodiversity were burned to give rise to fragile pastures resulting from a logic focused more on land appropriation than the creation and consolidation of wealth.

Similarly, technological innovation focused on increasing productivity and/or reducing costs, especially by reducing labor. However, this dynamic was based on a short-term microeconomic vision, with practically no concern for negative externalities and the lack of broader sustainability. Thus, many chemical inputs that were important for increasing production also polluted the environment, leaving toxic residues in food products and creating other negative effects. In many locations, inadequate use of irrigation resulted in soil salinization and water-table pollution, making them practically infertiles. Moreover, excessive mechanization and trampling due to intensive livestock farming compacted soils, causing erosion and fertility losses.

In practice, the production systems adopted so far resulted in a vicious circle that demanded the incorporation of increasing amounts of land and technology to offset losses in productivity

10. Ph.D. in Economics Associated Professor at the Economics Institute of the University of Campinas, State of São Paulo, Brazil, and Senior Researcher at the National Institute for Science and Technology in Public Policies, Strategy and Development – INCT-PPED.

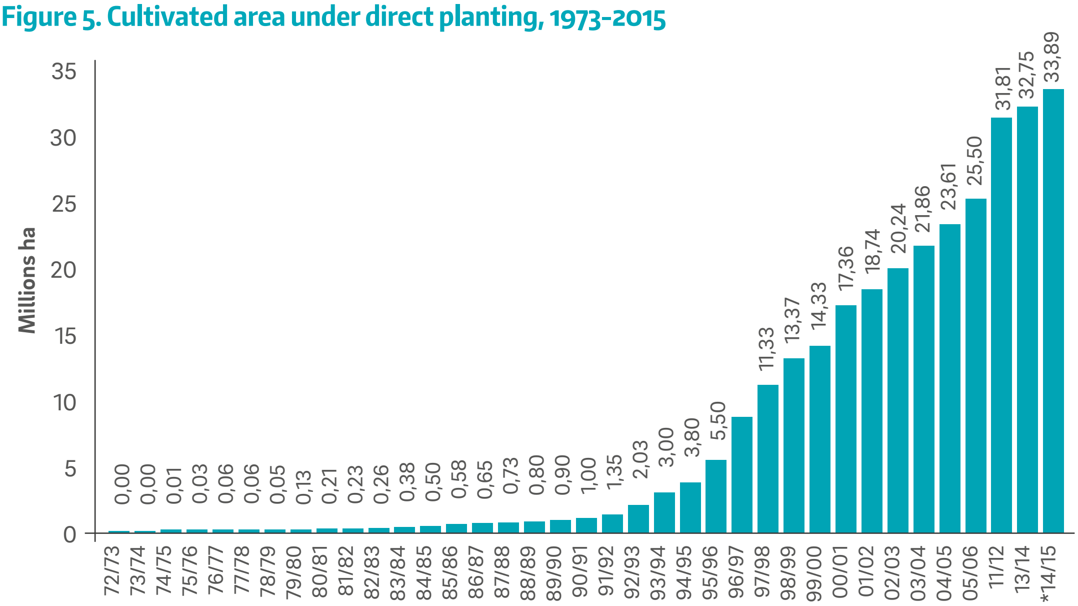
caused partly by the very low productive system and technology employed. Efficiency was not the focus, not beyond a strictly micro point of view, and even then, was limited to the short- and medium-term. It seemed it would always be possible to compensate for the loss in fertility through the incorporation of new land and new technology, and to make up for negative externalities with innovation. The aim here is obviously not to criticize the past, particularly since this took place within a different historical context, but to recognize the unsustainability of that production pattern and identify future challenges and opportunities for a paradigm shift.

Challenges and opportunities to increase the efficiency of food chains

In the current situation, marked by severe environmental and institutional restrictions, systemic efficiency takes a central role when it comes to addressing the food challenge. In contemporary society, it is no longer possible to only consider technical parameters to inform decisions regarding what, how much, how and for whom to produce. We must bear in mind the fact that nowadays, these decisions must obtain social approval through a wider and more complex mechanism than markets, which in the past enjoyed practically sovereign powers when it came to approving or rejecting decisions from economic agents.

In this new context, it is not enough for a technology or a productive plant to be efficient from the technical and economic standpoint. They must also be pre-approved by society, whose opinions are represented by interest groups, social movements, advocates for specific causes, consumer protection organizations, NGO, and public and private regulatory agencies. This dynamic places certain constraints on the traditional expected results of technological efficiency, since decisions made by the public and private sectors are based on contexts that emerge from the power play involving stakeholders which would not necessarily pass any tests considering rationality, cost-benefit and economic feasibility. These decisions are often full of contradictions and antagonisms, but are still legitimate in the context of democratic societies. This means the challenge of increasing the efficiency of agribusiness production chains is not limited to technical aspects, and must necessarily incorporate their social, environmental and political dimensions; and also, that this operation requires reconciliation of conflicting interests.

Figure 5. Cultivated area under direct planting, 1973-2015



Source: Embrapa/SGI.-September/2016

Despite the progress made by Brazilian agribusiness, there are still enormous opportunities to increase efficiency, at every stage of the production chain, from producer to the final consumer. In farms, increasing efficiency in agriculture involves the following lines of action:

i. Investment in the expansion of the innovation frontier, focusing on working with the most dynamic, technologically advanced producers, reducing waste and external consequences and improving the conservation of natural resources; and creating economies of scope by using and re-using waste and recovering by-products. We can already see some positive and promising trends in this field, such as 356-day agriculture, which enables nearly continuous use of the land through the year, the partial and full use of crop-livestock-forest integration systems, and precision agriculture. On this front, investment in R&D are the most important, although not the only, determinant of potential and real efficiency gains.
ii. Investing in the increase of average efficiency, exploring internal frontiers through efficiency gains for producers who are lagging behind. This will probably be a more complex challenge than the first. The relative delay is not caused by the lack of appropriate technology for the conditions faced by producers/regions with lower efficiency, but to the lack of conditions for innovation, which involves a wide range of variables and the environment itself, which is not conducive to innovation. The effort here is to focus on the key factors that hamper the incorporation of innovations that are already widespread in the country, such as financing, rural extension and technical assistance, training, market access and institutional strengthening.
iii. A key source for increasing system efficiency is the incorporation of resources that are currently idle but have the potential to be used. Some of these idle resources, abandoned because of previous unsustainable use or due to becoming economically unfeasible, for various reasons, could be efficiently reincorporated into production, using means made available by the technical and scientific progress made in the past 25 years. There are also resources that were never part of the system, such as idle lands in the suburbs and urban and domestic allotments. This involves the use of "neglected resources", which were redundant in the previous context of abundant resources, and whose utilization has been made feasible by new institutions and their determinants. This is a new agriculture, already a reality in many urban areas and countries, which tends to grow as restrictions on deforesting increase and the sustainability paradigm is implemented.

Another source of efficiency increase is the infrastructure and logistics of agribusiness chains, which have an enormous deficit with various effects on efficiency (Oliveira, 2014). From a micro point of view, the most important factor is the deficit in storage capacity, which prevents producers from taking advantage of market changes to buy and sell inputs and products at the best possible time. Likewise, effective access to electric energy in rural areas would enable significant efficiency gains for producers, especially in activities where refrigeration is relevant, such as the production of dairy products, fruits and vegetables.

From a more systemic point of view, beyond the limits of the farm, the greatest deficit and potential source of efficiency gains lies in transportation logistics. This deficit has many implications beyond elevating costs with inputs and reducing the price paid to the producer, due to the application of a discount on the reference price, equivalent to transport costs. It is also responsible for production losses along transport corridors, quality losses, animal welfare losses and high risks, including the risk of contamination, adulteration, theft and accident, which cannot always be compensated for by costly insurance. This is one of the reasons for the presence of extensive livestock farming in many areas, and for the infeasibility of small-scale production in others. In fact, small producers, who could use these resources in an intensive, sustainable and efficient manner, are excluded from it due to their inability to access the markets. Contrary to common belief, the problem is not the scale, but rather the logistics of transport, which involves high costs, therefore limiting the feasibility of transactions with higher-scale producers. The availability of a wide road network, including local roads, would reduce this disadvantage and make the intensive utilization of resources possible for small- and medium-scale farmers.

There is a very high level of waste at all levels of the food chain. This begins with the producer, who wastes some of the harvest/production due to handling issues, lack of infrastructure, information access. It happens again during transportation from the farm to commercial points, with grains falling off trucks, cold cargo compromised during transport routes and cargo theft. During storage, technical breaks may also be higher than justifiable, due to poor drying, precarious facilities and power outages. During processing, many products are still only partially used. This could be greatly improved, with considerable efficiency gains associated with economies-of-scope. In addition, in the distribution stage, the waste can be shocking. To see this, all you have to do is to visit the facilities of the Central Market Distribution Center (CEASA) at the end of the day, or walk by the waste containers of a supermarket chain. This loss is not limited to fruits and vegetables, as may be assumed, but also includes expired food products and storage problems in commercial venues themselves. Finally, we have the consumer, especially those with higher incomes, raised in a culture of abundance and high inflation, who do not concern themselves with the goal of avoiding food waste.

Final remarks

Any analysis of the possibilities of increasing efficiency in the Brazilian food-production system must consider one of the main sources of loss of the efficiency in international competitiveness in the national agricultural food system, due to the Brazil Cost. This cost includes excessive bureaucracy, a logistics deficit, high interest rates and high transaction costs related to judicial insecurity and institutional risks, which affect Brazilian society and its economy. Macroeconomic policies, marked by the legacy of inflation and the tension between fiscal responsibility and populist expansionism, maintain a certain bias of taxation over agricultural production, leading to pecuniary losses for producers and consumers.

In conclusion, there are opportunities for efficiency gains at every stage of the agribusiness chain. These opportunities represent an enormous frontier for production expansion and must be explored as part of the sustainable development challenge. The challenges we face today demand new institutional agreements to mobilize resources and powers that exist far beyond the capacities of the state. In this regard, it is the State's duty - an innovative duty in the Brazilian context - to create a favorable environment for the innovation of encouraging the sustainable mobilization of resources from the private sector to finance and enable actions consistent with the country's macro strategic objectives; and to promote public-private cooperation and partnership in research and development, overcoming the traditional view that places the main burden either on the state or on the private sector. In the case of Brazil, the efficiency and sustainability of the agri-food system is also linked to the capacity of decreasing the structural heterogeneity characteristic of agriculture and of incorporating a significant number of producers who were left on the sidelines of the progress that occurred in the past few decades, and which could be viable with the support of steady improvements in institutional arrangements and consistent policies (Vieira Filho and Gasques, 2016).

6. Health Considerations

Marilia R. Nutti[11] and Cleber Oliveira Soares

Foodborne Diseases

There are approximately 250 types of FoodBorne Diseases (FBD), many of which are caused by pathogenic microorganisms responsible for serious public health problems and significant

11. Senior Reseacher at Embrapa Food Technology.

economic losses. The syndromes resulting from the ingestion of food contaminated by these microorganisms are known as FBD (WHO, 2003; Popkin & Larsen, 2004). FBD can be identified when one or more persons present similar symptoms after eating food contaminated with pathogenic microorganisms, their toxins, toxic chemicals or harmful objects, forming a common source. In the case of highly virulent pathogens such as *Clostridium (C.) botulinum* and *Escherichia (E.) coli* O157: H7, it is assumed that a sole case can be considered an outbreak (WHO, 2004; Claro et al., 2015). Most outbreaks have been linked to the intake of foods with good appearance, and odor without any visible organoleptic change. This is because the dose infecting foodborne pathogens is usually less than the amount of microorganisms needed to degrade food. These facts make it difficult to trace food outbreaks, since consumers find it difficult to identify the source of FBD.

The lack of a specific association between the other foods and etiologies highlights the potential roles of cross-contamination, environmental contamination and the role of the infected food handler along the food chain from farm to fork (Claro et al., 2015). In Brazil, the epidemiological profile of FBD is little known. Only a few states or municipalities have statistics and data on etiological agents, the most commonly affected foods, and populations and high-risk populations. According to the available data on outbreaks, they are usually of bacterial origin, involving *Salmonella* spp., *E. coli, Staphylococcus aureus*, *Shigella* spp., *Bacillus cereus* and *Clostridium perfringens* (Ministério da Saúde, 2011).

Food security, the sound health of herds, the safeness and security of supply chains, biosecurity of food and the risk of bioterrorism have become matters of global concern. At the same time, the development and intensification of animal breeding, health and nutrition management through genetic improvement programs, better husbandry practices and the generation of more efficient inputs contribute to increasing yields while promoting food quality and safety in Brazil.

Meat, milk and their derivatives are the most important dietary components for humankind and are strategic for the Brazilian economy, since Brazil is a major producer of animal protein and the world's largest beef exporter (Abiec, 2016). However, these foods account for most of the pathogens transmitted to humans, causing FBD. In Brazil, with a population over 200 million people, 6,632 FBD outbreaks, with 118,104 patients and 109 deaths, were reported between 2007 and 2016. Most of these outbreaks were caused by bacteria, *Salmonella* spp. being the main agent, followed by *E. coli* and *S. aureus* (BRAZIL, 2016).

Among ruminants, Transmissible Spongiform Encephalopathies (TSE) is a matter of worldwide concern. These rare diseases caused by prions that affect humans as well as domestic and wild animals. They are neurodegenerative and lethal, with long incubation periods. Bovine Spongiform Encephalopathy (BSE) is the most important TSE, since it is considered a zoonosis. Since the diagnosis of BSE in several countries in Europe and North America, and the hypothesis of a relationship between this bovine disease and Creutzfeldt-Jakob Disease (CJD), as a new variant of a similar disorder in humans, biosafety in the cattle production chain has become a focus of attention for both consumers and the beef industry. In this context, and despite the occurrence and record of BSE in the world, including the Americas, risks of existence and occurrence of this serious disease in Brazil are insignificant.

Brazilian beef and milk production systems are almost exclusively based on pastures, resulting in a comparative advantage through relatively low production costs as well as a competitive advantage from farming "green cattle", which is a safe product, with quality features highly valued by the market. Thus, the country is exploring the potential of cattle farming in pastures, while ensuring sound animal health and preventing TSE in Brazilian herds. Given these productive and technical factors, Brazil has been classified by the OIE (World Organization for Animal Health) as a country with negligible risk for BSE (OIE, 2016).

Transition/Overconsumption

Since the second half of the 20th Century, favorable conditions for the occurrence of infectious diseases have been gradually replaced by a favorable scenario for the occurrence of Chronic Non-Communicable

Diseases (NCD) including obesity, diabetes mellitus, CardioVascular Disease (CVD) such as hypertension and strokes, and certain types of cancer related to excessive/unbalanced food consumption and/or insufficient physical activity. Chronic NCD are increasingly becoming significant causes of disability and premature death in both developing and newly developed countries, placing additional burdens on already overtaxed national health budgets (WHO, 2003). This scenario is visible in both developed countries and developing countries, including Brazil (Popkin & Larsen, 2004). In this context, the 2003 Global Strategy of the World Health Organization (WHO) for Diet, Health and Physical Activity reinforces the need for improvement of the world food-consumption pattern, focusing the reduction in the consumption of foods with high energy, low levels of nutrients and high levels of sodium, saturated fats, trans fats and refined carbohydrates (WHO, 2003; WHO, 2004). The Global Strategy indicates that to achieve the best results in preventing chronic diseases, the strategies and policies that are applied must fully recognize the essential role of diet, nutrition and physical activity (WHO, 2003).

Claro et al., 2015, found that studies on Brazilians'' eating habits trends in the last decades emphasize the increase in the consumption of meat and industrialized foods (soft drinks, cookies and frozen meals) and the reduction in the consumption of pulses, roots and tubers, fruits and vegetables. Based on these facts the Ministry of Health developed, along with other measures, the 2011-2022 Brazilian Strategic Action Plan to Combat Chronic Non-Communicable Diseases (NCD) in 2011, and re-edited the 'Dietary Guidelines for the Brazilian Population: Promoting a Healthy Diet', in 2014. (Ministério da Saúde, 2014).

The 2011-2022 Strategic Action Plan to Combat Chronic Non-Communicable Diseases (NCD) in Brazil, from the Ministry of Health, prioritizes the reduction of the population's exposure to risk factors, and incentives for protective factors, aiming at expanding measures to protect health: creating spaces for engaging in physical activity, prohibiting cigarette advertisement, creating smoking-free places, in addition to supporting healthy lifestyles for a better quality of life and well-being among the population (Ministério da Saúde, 2011). The latest edition of the "Dietary Guidelines for the Brazilian Population: Promoting a Healthy Diet", in 2014, emphasizes the consumption of *in natura* or minimally processed foods, especially vegetables, over soft drinks and sweets.

Preventive actions against NCD to promote health should take into account diet, nutrition and physical-activity factors, suggesting an alliance between the Ministry of Health, the Ministry of Agriculture and the Ministry of Education, in terms of their respective roles in establishing dietary guidance, policies regarding production of healthier foods and advocacy for healthier diets and physical activities.

Nutrition-sensitive Interventions

The acceleration of progress in nutrition requires effective, large-scale nutrition-sensitive programs (Ruel & Alderman, 2013). So far, most efforts to fight micronutrient deficiency in developing countries have focused on providing vitamin and mineral supplements for target populations and on fortifying foods with these nutrients (Nutti & Viana, 2015). Targeted agricultural programs can complement these investments (Ruel & Alderman, 2013).

The introduction of bio-fortified crops – varieties bred for increased mineral and vitamin content – could complement existing interventions and provide a sustainable, low-cost way of combatting malnutrition. In Brazil, research and development of bio-fortified foods have highlighted a unique aspect - Brazil is the only country where eight different crops are studied at the same time, namely squash, rice, sweet potatoes, beans, cowpeas, cassava, maize and wheat in an attempt to obtain more nutritious cultivars with good agronomic qualities and market acceptance (Nutti & Viana, 2015).

The project has been prioritizing the states of Maranhão, Piauí and Sergipe, due to their low Human Development Index (HDI) compared with the other states. Approximately 200 researchers, technicians and partners are engaged and 11 cultivars have been developed with higher iron, zinc or pro-vitamin A since 2005. Around 120 demonstrative units have been implemented, reaching an average of 20,000 people. By 2018, the target is to reach 1 million households, equivalent to approximately 4 million people (Nutti & Viana, 2015).

Nutrition-sensitive programs can help create an environment in which young children can grow and develop to their full potential. When combined, early child development and nutrition interventions show promising synergistic effects that could lead to substantial improvements in efficiency, effectiveness and cost effectiveness (Ruel & Alderman, 2013).

7. Policy Considerations

Geraldo B. Martha Jr. and Cleber Oliveira Soares

Introduction

Brazilian agricultural policies have traditionally prioritized rural credit, agricultural research and rural extension. Rural extension, in fact, lost impetus in the 1980s and in the 1990s, and had a poor outcome from the 2000s onward. These policies were largely designed and implemented to alleviate the distortionary pressures imposed on the agricultural sector by the policies implemented to protect Brazil's national industry, especially from the 1960s to mid-1980s. After that period, the scope of agricultural sectoral policies was thoroughly reviewed and curtailed to accommodate the lack-of-resources reality brought about by the country's severe macroeconomic crises in the 1980s and 1990s (Martha & Alves, 2017).

In the past two decades, a set of novel policies and actions were implemented to improve the planning and financing of agricultural production in the XXIst century. The Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA), in coordination with other key ministries, has been able to offer opportunities to finance investments in cooperatives, machinery purchasing, irrigation systems and storage facilities. Increasing emphasis has also been placed on risk management (insurance) and marketing approaches.[12]

Policies targeting family and medium-sized agriculture, as well as policies to foster the adoption of better and improved agricultural practices, with reduced negative impacts on the wider environment, have gained increased attention. For example, one of the major policies for Brazilian agriculture over the past five years has been MAPA's Low Carbon Agriculture - ABC Program. The funding of this Program is intended to enable farmers to invest in technologies to increase systems' resilience, to improve the conservation of natural resources and to reduce the intensity and overall Greenhouse Gas Emissions (GGE) in Brazilian agriculture. This program has become a world reference in recent years.

Food policies have been implemented to offer nutrition assistance by providing affordable food for the poor population. Additionally, the nutritional perspective (malnourishment versus obesity), considering consumers' diets and their quality, has been a growing trend in policy-making (Embrapa, 2014).

Until the late 1990s, incentives for Brazilian agriculture were negative because of the transfer of resources from agriculture to other sectors – particularly to industry. On the basis of the the Organization for Economic Cooperation and Development (OECD)'s data, it is possible to calculate that the annual level of incentives to Brazilian agriculture – the Producer Support Estimate (PSE) – averaged only 1.6% of farms' gross incomes from 1995 to 2014. This clearly indicates Brazilian agriculture's enormous vulnerability to market signals, meaning that technologies and production decisions, whatever the goal (food and nutrition security in domestic market or abroad, biomass for energy or bio-industry, etc.), will strongly respond to farmers' perception of relative prices.

12. For example, tools and mechanisms to avoid dramatic fluctuations in farmers' income and consumer prices (minimal pricing policies, governmental stocks, etc.) were part of the agricultural policy portfolio. For details, please see MAPA's agricultural policy approach at http://www.agricultura.gov.br/politica-agricola.

Brazil's National Food and Nutrition Security Plan

Over the past decades, Brazil successfully transformed its agriculture and significantly improved the availability of high-quality food for its population (**Figures 3 and 6**). Nevertheless, the share of the population facing severe food insecurity in the country still amounted to 7.2% of the population in 2013 (IBGE, 2016). This situation must obviously be addressed to achieve a complete food-security scenario in Brazil.

Brazil launched in 2011 the first National Food and Nutrition Security Plan. Following the analysis of results and achievements for this first policy cycle, an updated and reviewed plan was made available in 2016 - the "Second National Food and Nutrition Security Plan".[13] The plan derived from the 5th National Conference on Food and Nutrition Security, held in November 2015, under the coordination of the National Council for Food and Nutrition Security (CONSEA).

The Second "National Plan for Food and Nutrition Security" has a time horizon from 2016 to 2019, and consists of 121 goals and 99 related actions that were structured according to nine major challenges: (1) to promote universal access to adequate and healthy food, prioritizing the population under a food and nutritional insecurity condition; (2) to combat food and nutritional insecurity and to foster the productive inclusion of vulnerable population groups, such as traditional communities and persons and other vulnerable populations; (3) to promote the production of healthy and sustainable food, the structuring of family agriculture and the strengthening of agroecological production systems; (4) to supply and provide regular access to adequate, healthy food to the Brazilian population; (5) to promote and protect adequate and healthy food for the Brazilian Population, with strategies for food and nutritional education and regulatory measures; (6) to prevent and control injuries and health problems due to poor diets; (7) to improve water availability and access for the population, especially the rural poor; (8) to consolidate the implementation of the "National Food and Nutrition Security System (SISAN)" through improved federal management, intersectoral relationships and social participation, and (9) to support initiatives for promoting sovereignty, food and nutritional security and human rights to adequate food, and democratic, healthy and sustainable food systems at the international level, through dialogue and international cooperation.

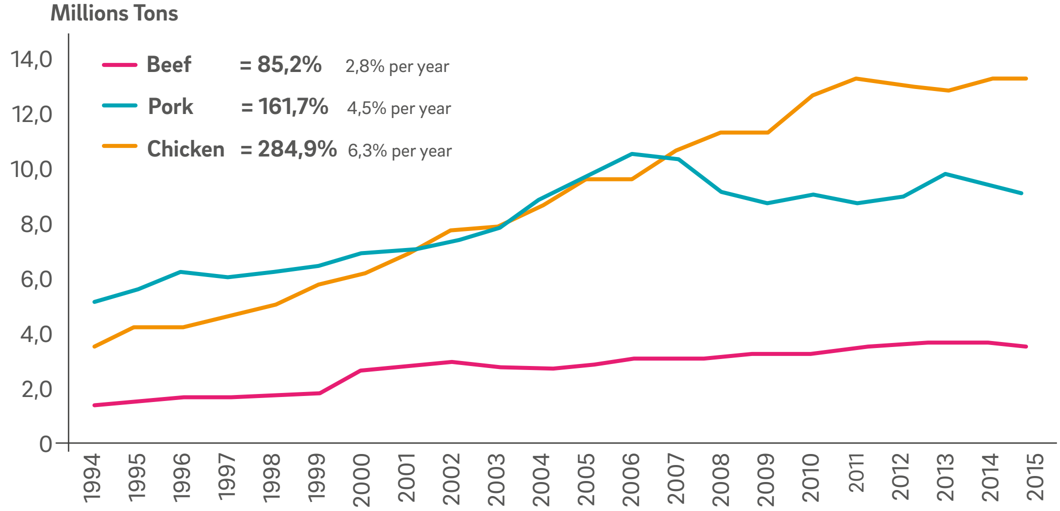
13. For details, please see information available at: http://www4.planalto.gov.br/consea/comunicacao/noticias/2016/plano-nacional-de-seguranca-alimentar-e-nutricional-ja-esta-disponivel-na-internet

Policies-at-large

During the modernization of agriculture, the sector progressively became more exposed and affected by generic policies, such as monetary policies, the exchange rate and income policies. As "macro-prices" change they eventually translate into fairly challenging investment perspectives for entrepreneurs (business and financial risks) and ultimately, into the success of businesses. By reducing risks, more stable, predictable and sound generic policies will in due course favor investments along the agricultural value chains. From the perspective of the agricultural sector, strengthening the insurance system and its effectiveness is a top priority.

The research-driven strategy behind Brazilian agriculture offered the necessary flow of knowledge and technologies, which in turn, provided farmers with the tools they needed to transform traditional agriculture into a highly competitive, increasingly sustainable sector based on science and technology. Strengthening investment in agricultural R&D will be crucial to Brazil's prospects for agricultural production and sustainability, food and nutritional security and macro-economic stability and economy growth. An important approach to be emphasized and pursued is to sizably increase the private sector's investments in agricultural R&D activities. Sometimes the private sector will undertake R&D activities on its own but sometimes this will happen in partnership with the public sector. In the end, the overall objective is to make Brazilian agriculture more resilient to upcoming biotic and abiotic challenges, and better prepared to leverage future opportunities (Martha et al., 2016).

Figure 6. Brazil: Beef, Chicken and Pork Production, 1994-2015



Sources: Conab. Reference Source: Embrapa/SGI.

Last, but certainly not least, the ability of technologies and human capital to foster agricultural sustainability and competitiveness is not only limited by scientific knowledge and marketable abilities, but also by non-technological factors. Bottlenecks in logistics, storage and transport infrastructure, the availability and cost of energy, among other factors, such as the lack of qualified human capital in agriculture, will work as headwinds to successful technology adoption, agricultural expansion and a more food-secure scenario. Perhaps less evident, is the need to focus on reducing market imperfections to ensure that modern technologies will be effectively adopted on different scales and in a more inclusive way on Brazilian farms.

8. Further Challenges and Achievements

Geraldo Magela Callegaro[14]

A comprehensive analysis of the main science and technology indicators for agricultural research and development in Brazil presented in the EMBRAPA-IFPRI study[15] made it possible to trace the evolution of the impacts of technologies and the overall contributions of Embrapa to Brazil's agricultural development.[16]

According to the study, during the 2006–2013 period, agricultural R&D spending rose by 46% due to growth at Embrapa and in the higher-education sector, particularly among federal universities. At 1.8%, spending as a share of Agricultural GDP is the highest in Latin America. Brazil employs the largest number of qualified agricultural researchers with doctorates in Latin America, and its 73% share of researchers with doctoral degrees is the highest by far. A complete fact-sheet[17] on agricultural research and development in Brazil, among other facts, shows that the country leads investment in R&D&I and the number of highly qualified researchers.

Embrapa is widely referred to as a successful case of investment in R&D&I and of its experience of sharing with other countries to improve food and nutrition security as well as to boost

14. International Consultant on Agricultural Development.

15. http://www.asti.cgiar.org/brazil

16. ASTI, IDB & EMBRAPA. Agricultural R&D Indicators Factsheet, April 2016. See https://www.asti.cgiar.org/pdf/factsheets/Brazil-Factsheet.pdf

17. ASTI, IDB & EMBRAPA. Agricultural R&D Indicators Factsheet, 2006-2013. April 2016.

farmers' incomes and foreign exchange revenues for strengthening the economies of developing countries.

On another front, the National Project for Technological Innovation for the Improvement of Animal and Plant Health, financed by the National Research Council (CNPq) used a new approach to tackle animal and plant sanitary and health issues. It created a strong nationwide-applied research network with State and Federal Universities: the Ministry of Agriculture, Livestock and Supply; Ministry of Health; National Agency for Sanitary Surveillances (ANVISA); State Secretariat of Health; Secretariat of Agriculture; Research State Organizations, and Farmers' Associations.

As a result, several research actions and training activities benefited many production areas and professionals trained nationwide. A couple of professional Master Programs in Animal and Plant Health and Sanitary Issues are now in place at several universities across the country, taught by many experts, including some from developing countries.

Despite these achievements, some constraints continue to block future technology adoption and research implementation, as outlined below.

Challenges and options for improving R&D&I

Key constraints on the future of technology, research and innovations for agricultural development involve institutional and managerial decisions waiting for action by governments at the federal and state levels.

National and international regulations for procuring equipment, spare parts and biochemical materials for in-house laboratory and field trials need revisions and improvements regarding some of their cumbersome purchase procedures. This would avoid long delays in the acquisition of inputs for research activities. Although Embrapa and other research organizations and universities have pressured public authorities to remove these awkward regulations for a long time, however, the results have been disappointing.

There is also a need to enhance national and international public-private partnerships for the design, preparation, financing, continuation, monitoring and evaluation of research projects for generating and adapting technologies and innovations to increase the competitiveness and sustainability of the main global production chains underway in the country and abroad. These partnerships should include organizations for technical cooperation such as FAO, PNUD, IICA and some national and international financial institutions such as the World Bank, IDB, and EU. Both cases would result in synergies, to facilitate the efforts of Embrapa to assist developing countries to implement much-needed institutional reforms to strengthen and consolidate agricultural research organizations.

Imports of new inputs and technologies should be facilitated, and researchers should be allowed to participate in short-term capacity-building programs in international research and teaching organizations to update staff on new techniques for their current research projects in Brazil and abroad. Even though some years ago, Embrapa created a set of international offices in certain high-tech countries, this initiative should be enhanced to allow for the participation of a larger number of researchers, including those from state research organizations, to become an efficient instrument for the prompt absorption of new knowledgment, technology and innovations.

Embrapa should make more of an effort to help developing countries reform and strengthen their agricultural research organizations to enable them to become sustainable and highly proactive and reactive to farmers' technological demands. This should provide farmers with suitable technologies to boost their agriculture production, mainly in terms of staple foods to improve food and nutritional security, in countries with widespread malnutrition that are highly dependent on domestic agricultural production, due to the lack of foreign exchange to import staple foods.

Challenges regarding logistics

Several agricultural and livestock production areas in Brazil are in the Center-West, North and NE regions, with less developed infrastructure for storage, agro-processing and transportation facilities, which cause great losses in the quality and quantity of agricultural production. This type of infrastructure is urgently needed to improve farmers' income and lower the prices of consumer products, in both national and international markets. Although farm level agricultural production costs are much lower than those of their competitors, the prices of Brazilian commodities are still less competitive in international markets, because of the regressive effects of the so-called '*Brazil cost*'.

Several policy measures are attempting to address the Brazil cost, including the national plan for the construction and improvement of roads and railroads; reductions in the administrative and social cost of labor; privatizations and concessions of roads and railroads, among other measures. However, the results of these measures have been limited due to the lack of investment, delays in the revision and approval of friendly regulations and the lack of continuous, coordinated pressure from stakeholders.

Population's access to food

An efficient network of supermarkets and other types of commercial stores facilitates the distribution of all kinds of food products, including their availability in rural areas. The Bolsa Familia Program operates a cash transfer, through a bankcard, which provides poor families with a monthly amount to complement their income to buy food. However, if an adult family member gets a formal job, with a fixed salary, the amount of the cash transfer declines or the family may no longer be entitled to the grant, depending on the new income of the family, as part of the exit strategy from the Program.

Challenges and opportunities of climate change

Climate change has been a deterrent to maintaining or even increasing hydroelectric energy production to meet demand in almost all states, resulting from the reduction and/or irregular distributions of rainfalls year round. This situation has put pressure on the public sector to investing technologically advanced power plants and on alternative sustainable energy sources, mainly solar and wind, to increase the national electricity supply.

Climate change is therefore an opportunity for the development of energy saving technologies and innovations through new instruments for capturing solar and wind energy, for household, industrial and agricultural consumption, in a situation of lower hydroelectric generation, due to the reduction of the volume of water in rivers. In fact, in the past ten years, electricity from wind power plants has been growing at over 15%/year, becoming an important alternative source of energy to offset the losses in the electricity supply from hydroelectric power plants. However, the slow construction of power lines for transmission of this electricity is blocking its supply, acting as a disincentive for further private investment.

Food and nutrition security by gender

In general, gender impacts food and nutrition security in two ways. The first, and most common one, is when the man is the head of the household. In this case, the allocation of income for food and nutrition is based on his own criteria, with or without the woman's participation, which may have regressive effects on the availability of the recommended daily allowance of nutritional food for the family. In the second case, having a woman as the head of the family, working in or outside home, improves the family's food and nutritional security, assuming that she is committed to the well-being of the family, which is usually the case.

Food production for human consumption and other uses

Brazilian agricultural production supplies national and international markets for human and non-human consumption. In general, the bulk of agricultural production from medium and large farmers is used for human consumption, agro-processing and for livestock feeding, while the remainder of production is exported. Since the largest proportion of exports of agricultural production is in natura, any increase in agro-processing would increase the revenue for production chains. There is therefore great scope for increasing investment in agro-processing facilities.

There is no significant competition in production areas for sugarcane or areas assigned for the production of staple foods, in the state of São Paulo and the coastal areas of the NE region, where there are sugar cane plantations. The same is true for rice in the states of Rio Grande do Sul and Goias; and black and red beans in the inland states of Minas Gerais, Bahia, and elsewhere. This is so, because large areas of these crops are grown in various geographic locations, with little competition for land.

In general, in the Center-West, North and NE regions, small low-income farmers allocate the largest proportion of their production of staple food for self-consumption, because of their eating habits and the need to maintain stocks for food security, in the event of future harvest failures, because of unexpected droughts.

Capacity building for skilled and non-skilled labor

Private and public middle and high schools and universities provide formal training for those wishing to work in the agricultural sector, in agricultural campuses distributed across the country. The same is true of the non-formal short-term training provided by public and private organizations, which includes the National Service for Capacity Building for Rural Activities (SENAR), in the Ministry of Agriculture, Livestock and Supply (MAPA), and the National Service for Small Business (SEBRAE), in the Ministry of Development, Industry and Trade.

Major technological achievements of the Brazilian agricultural sector

Some of the key achievements of the agricultural sector that contributed for a deep transformation of traditional Brazilian agriculture are as follows.

Crop and livestock genetics improvements

This resulted from long-term plant and animal genetic improvement programs. As an example, the breaking of the photoperiod of soybeans production, from mid-October to mid-November, allowing widespread soybeans production, all over the country, and all year round. This strongly contributed to become Brazil one of the largest producer of this cereal in the world. Other genetics improvements occurred in cereals, livestock, orange and some fruit trees leading the country to very high production positions in the world.

Improvements in pest management

Biological control of virus in soybeans production resulted in huge cost savings in pesticides use, including positive effects on environmental protection, with substantial gains in yields and production of healthy cereal for human and animal consumption. There were others biological controls in other crops, like the white fly in melons and some fruit trees, with important pecuniary and productivity gains, cum environmental protection.

Soil management

The direct planting currently widespread adopted in more than 33 million hectares of cereal production had important progressive effects on soil protection, conservation and improvement of its physical, chemical and biological conditions overtime. This is one of the most important achievements for sustainable agricultural production around the world.

Agricultural-Livestock-forestry production systems

These kinds of integrated production systems are good examples of well-balanced, sustainable, and profitable production mixed, with widespread use across the country, by several types of farmers, with improvements on soil, water and vegetation conditions, mainly in tropical rain forest areas and also in others areas of the country.

Sustainable development of savannahs

The development of technological packages for crops and livestock production allowed for sustainable and competitive integration of Brazilian savannahs (Cerrados) into the national production system, creating one of the most important agricultural production *el dorado* in the world, covering large areas of Center-West, North and NE regions of Brazil.

Development of key production chains

Regular investment in agricultural research, production and marketing extension permitted the development and improvement of key production chains, such poultry, hogs, corn, cereals, fruit, and cattle, among others. These production chains ensured food and nutrition security for national consumers and provided a large surplus for export. The increase in the domestic supply of such products, strongly contributed to a continuous decline in the real prices of the food basket, working as a positive income effect for consumers. Moreover, the development of these key production chains became a reference for many developing countries, and it is widely referred to as an example of good agricultural-production practices in the tropics.

Basic public supporting services for development

It is worthnoting the cases of a set of successful supporting services, that have given farmers access to basic services, including technologies and innovations, through the National Program for Family Agriculture (PRONAF); National Service for Small Business (SEBRA); Rural Credit for medium and large farmers; Rural extension; Agricultural research through Embrapa, Universities, Teaching and Research Institutes, and State Organizations. These services are currently benchmarks for certain developing countries, because of their orientation to small, medium and large family farmers.

References

Section 1. Brazil's National Characteristics

Alves, E.R.A.; Souza, G.S.; Rocha, D.P. Marra, R. Fatos marcantes da agricultura brasileira. In: Alves, E.R.A.; Souza, G.S.; Gomes, E.G. (Eds.) Contribuições da Embrapa para o desenvolvimento da agricultura no Brasil. Brasília: Embrapa, 2013. p.13-45.

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa, 2014. 194p.

FAO. Food and Agriculture Organization. Land resource potential and constraints at regional and country levels, World Soil Resources Report, 90. Rome: FAO, 2000.

IBGE. Instituto Brasileiro de Geografia e Estatística. Área territorial brasileira. Available at < http://www.ibge.gov.br/home/geociencias/cartografia/default_territ_area.shtm > Accessed on November 29th, 2016a.

IBGE. Instituto Brasileiro de Geografia e Estatística. Indicadores sociais municipais: uma análise dos resultados do universo do censo demográfico 2010. Available at: http://www.ibge.gov.br/home/estatistica/populacao/censo2010/indicadores_sociais_municipais/indicadores_sociais_municipais.pdf Acessed on Feb. 15th, 2011.

IBGE. Instituto Brasileiro de Geografia e Estatística. Uma análise das condições de vida da população brasileira 2015. Available at < http://www.ibge.gov.br/home/estatistica/populacao/condicaodevida/indicadoresminimos/sinteseindicsociais2015/default_tab_xls.shtm > Accessed on November 29th, 2016b.

IBGE. Instituto Brasileiro de Geografia e Estatística. Pesquisa Nacional por Amostra de Domicílios. Segurança Alimentar: 2004/2013: Brasil, grandes regiões e unidades da federação. Available at < http://www.ibge.gov.br/home/estatistica/populacao/seguranca_alimentar_2013/default_xls_2013.shtm > Accessed on November 29th, 2016c.

Lopes, M.A. The Brazilian Agricultural Research for Development (ARD) System. In: Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings. Paris: OECD, 2012. p.323-338.

Martha Jr., G.B.; Alves, E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C. (Eds.) The Oxford Handbook of the Brazilian Economy (forthcoming, 2017).

Osorio, R. Desigualdade e pobreza. In: Calixtre, A.; Vaz, F. (Orgs.) PNAD 2014 – breves análises. 2014. p.7-11.

Rodríguez, A.; Dahlman, C.; Salmi, J. Knowledge and innovation for competition in Brazil. Washington, D.C.: World Bank, 2008. 247p.

WRI. World Resource Institute. World resources 2008: the roots of resilience – growing the wealth of the poor. Washington, D.C.: WRI, 2008.

Section 2. Institutional Setting

Alves, E. Embrapa: a successful case of institutional innovation. Revista de Política Agrícola, v.19, Special Issue, p.64-72, 2010.

Alves, E.R.A.; Souza, G.S.; Rocha, D.P. Marra, R. Fatos marcantes da agricultura brasileira. In: Alves, E.R.A.; Souza, G.S.; Gomes, E.G. (Eds.) Contribuições da Embrapa para o desenvolvimento da agricultura no Brasil. Brasília: Embrapa, 2013. p.13-45.

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa, 2014. 194p.

Flaherty, K.; Guiducci, R.C.N.; Torres, D.P.; Vedovoto, G.L.; Ávila, A.F.; Perez, S. Brazil: Agricultural R&D Factsheet, 2016. Available at www.asti.cgiar.org/brazil

Lopes, M.A. The Brazilian Agricultural Research for Development (ARD) System. In: "Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings. Paris: OECD, 2012. p. 323-338.

Martha, Jr. G.B.; Contini E.; Alves, E. Embrapa: its origins and change. In: The regional impact of national policies: the case of Brazil. Edited by Baer W. Northampton: Edward Elgar Publishers, 2012.

Martha Jr., G.B.; Alves, E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C.R. (Eds.) The Oxford Handbook of the Brazilian Economy. (2017, forthcoming).

Sowell, T. Wealth, poverty and politics: an international perspective. New York: Basic Books, 2015. 328p.

Section 3. Resource and Ecosystem Characteristics: Plant Production, Genetics and Biodiversity

Aidar, H. e Kluthcouski, J. 2003. Evolução das atividades lavoureira e pecuária nos cerrados. In: Kluthcouski, J.; Stone, L.F. e Aidar, H. (ed.). Integração lavoura-pecuária. Santo Antônio de Goiás: Embrapa Arroz e Feijão. p.25-58.

Balbino, L.C.; Cordeiro, L.A.M.; Oliveira, P.; Kluthcouski, J.; Galerani, P.R. e Vilela, L. 2012. Agricultura sustentável por meio da Integração Lavoura-Pecuária-Floresta (iLPF). Informações Agronômicas 138:1-19.

Conab. 2017. Acompanhamento da safra brasileira de grãos. V.4 – Safra 2016/17-N. 7 – Sétimo Levantamento, abril 2017. 160p.

Cong, L.; Ann Ran, F.; Cox, F.D.; Lin, S.; Barretto, R.; Habib, N.; Hsu, P.D-; Wu, X.; Jiang, W.; Marraffini, L.A. and Zhang, F. 2013. Multiplex genome engineering using CRISPR/Cas systems. Science 339 (6121): 819-823.

Convention on Biological Diversity 1992. https://www.cbd.int

Fonarce, K.M.; Drakeley, C.J.; William, T.; Espino, F.; and Cox, J. 2014. Mapping infectious disease landscapes: unmanned aerial vehicles and epidemiology. Trends in Parasitology 30(11): 514-519.

Fowler, C. 2016. Seed on Ice: Svalbard and the Global Seed Vault. 160p.

Geraldi, I.O. 2012. Contribution of graduate programs in plant breeding to the education of plant breeders in Brazil. Crop Breeding and Applied Biotechnology S2: 1-6.

Gibson, D.G.; Glass, J.I.; Lartigue, C.; Noskov, V.N.; Chuang, R.Y.; Algire, M.A.; Benders, G.A.; Montague, M.G.; Ma, L.; Moodie, M.M.; Merryman, C.; Vashee, S.; Krishnakumar, R.; Assad-Garcia, N.; Andrews-Pfannkoch, C.; Denisova, E.A.; Young, L.; Qi, Z.Q.; Segall-Shapiro, T.H.; Calvey, C.H.; Parmar, P.P.; Hutchison, C.A.; Smith, H.O. and Venter, J.C. 2010. Creation of a bacterial cell controlled by a chemically synthesized genome. Science 329 (5987): 52-56

Neufeldt, H.; Resck, D.V.S. and Ayarza, M.A. 2002. Texture and land-use effects on soil organic matter in Cerrado Oxisoils, Central Brazil. Geoderma 197(3-4): 151-164.

Paterniani, E. 2001. Agricultura sustentável nos Trópicos. Estudos Avançados 15 (43): 303-326.

Ramalho, M.P.; Toledo, F.H.R.B. e Souza, J.C. 2010. Melhoramento genético de plantas no Brasil. In: Compendio em melhoramento genético de plantas no Brasil. Ramalho, et al. (Ed). p.17-37.

Section 4. Technology and Innovation

Aalves, F.V.; Almeida, R.G.; Laura, V.A.; Silva, V.P.; Macedo, M.C.M.; Medeiros, S.R.; Ferreira, A.D.; Gomes, R.C.; Araújo, A.R.; Montagner, D.B.; Bungenstab, D.J.; Feijó, G.L.D. Carne Carbono Neutro: um novo conceito para carne sustentável produzida nos trópicos. Brasília, DF: Embrapa, 2015 (Embrapa Gado de Corte. Documentos, 210). Disponível em: <https://www.embrapa.br/gado-de-corte/busca-de-publicacoes/-/publicacao/busca/carne%20carbono%20neutro?>

CICARNE. Centro de Inteligência da Carne. Disponível em: <http://www.cicarne.com.br/> Acessed on December 29th, 2016.

Collins, J.P.; Heitman, E.; Achee, N.L.; Chandler, V.; Delborne, J.A.; Gaut, B.S.; Higgs, S.; Kaebnick, G.E.; Kingiri, A.; Landis, W.; Riddiford, L.; Tait, J.; Taneyhill, L.A.; Travis, J.; Turner, P.E.; Winickoff, D.E.; Sawyer, K.; Thévenon, A.; Miller, R.; Sharples, F.; Kolesnikova, A. Gene drives on the horizon: advancing science, navigating uncertainty, and aligning research with public values. Washington, D.C.: The National Academy of Sciences, Report in Brief, Jun. 2016. 4p.

Economist. Brazilian agriculture: the miracle of the cerrado. The Economist, August 26th, 2010. Available at < http://www.economist.com/node/16886442 > Accessed on August 28, 2010.

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa, 2014. 194p.

Erb. K.-H., Lauk, C., Kastner, T., Mayer, A., Theur. M.C., Haber, H. Exploring the biophysical option space for feeding the world without deforestation, Nature Communications, DOI: 10.1038/ncomms11382. 2016.

Fedoroff, N.V., Food and a future of 10 billion. Agriculture and Food Security. DOI 10.1186/s40066-015-0031-7. 2015.

Galvão, Cleber E.; Rosinha, Grácia Maria S.; Sanches, Cristiane C.; Elisei, Carina; Araújo, Flábio R.; Feijó, Gelson L. D.; Almeida Torres, Roberto Augusto; Soares, Cleber O. Polymorphisms of Intron 1 and the Promoter Region at the PRNP Gene in BSE-Free Caracu Cattle. Biochemical Genetics, v. 1, p. 1-13, 2012.

Gonçves, Aline N.D.; Soares, Cleber O.; Sanches, Simone C.; Reis, Fernando A.; Rosinha, Grácia Maria S. Genotypic profile of Pantanal creole sheep regarding susceptibility or resistance to scrapie. Pesquisa Agropecuária Brasileira, v. 51, p. 684-687, 2016.

IPCC–Intergovernmental Panel on Climate Change, 2006, IPCC. Guidelines for National Greenhouse Gas Inventories. Japan: IGES, v. 4, 2006.

Karvatte Jr., N.; Klosowski, E.S.; Almeida, R. G.; Mesquita, E. E.; Oliveira, C. C.; Alves, F.V. Shading effect on microclimate and thermal comfort indexes in integrated crop-livestock-forest systems in the Brazilian Midwest. International Journal of Biometeorology, v. 60, p. 1-9, 2016.

Martha Jr. G.B; Alves E.; Contini E. Land-saving approaches and beef production growth in Brazil. Agricultural Systems, v.110, p.173-177, 2012.

Martha Jr. G.B; Alves E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C. (Eds.) The Oxford Handbook of the Brazilian Economy (forthcoming, 2017).

Martin, V.J.J., Pitera, D.J., Withers, S.T., Newman, J.D., Keasling, D. Engineering a mevalonate pathway in Escherichia coli for production of terpenoids. Nature Bitoechnology 21, 796-802.

Medford, J.I., Prasad, A. Towards programmable genetic circuits. The Plant Journal, 87, 139-148. 2016

Melo, Elane S.P.; Souza, Ingred I.F. ; Ramos, Carlos A.N.; OsórioAna Luiza A.R.; Verbisck, Newton V.; Aráujo, Flábio R. Evaluation of the use of recombinant proteins of Mycobacterium bovis as antigens in intradermal tests for diagnosis of bovine tuberculosis. Archivos de Medicina Veterinaria, v. 47, p. 273-280, 2015.

Nielsen, A.A., Der, B.S., Shin, J., Vaidyanathan, V.P., Strychalski, E. A., Ross, D., Densmore, D., Voigt, C.A. Genetic circuit design automation. Science, 352, DOI: 10.1126/science.aac734.

Nemhauser, J.L., Torii, K. U. Plant synthetic biology for molecular engineering of signalling and development, Nature Plant, DOI: 10.1038/NPLANTS.2016.10

OIE – Organização Mundial de Sanidade Animal (2016). Estatus de los países miembros respecto de la encefalopatia espongiforme bovina. Resolución N° 20 (84ª Sesión General de la Asamblea Mundial, mayo de 2016). Disponível em: http://www.oie.int/es/sanidad-animal-en-el-mundo/estatus-sanitario-oficial/eeb/estatus-sanitario-oficial/. Acesso em 12 dez. 2016.

Pereira, P.A.A.; Martha Jr., G.B.; Santana, C.A.; Alves, E. The development of Brazilian agriculture: future technological challenges and opportunities. Agriculture and Food Security, v.1, n.4, 2012.

Rech, E.L., Arber, W. Biodiversity as a source for synthetic domestication of useful specific traits. Annals of Applied Biology 162:141-144. 2013.

Rech, E.L., Lopes, M.R. Insights into Brazilian agricultural structure and sustainable intensification of food production. Food and Energy Security 1:77-80. 2012.

Soares, Cleber O. PD&I alavanca a pecuária sustentável. Agroanalysis, v.43, n.11, p. 41. 2014.

UNDP (United Nations Population Division). World population prospects – The 2015 Revision: Highlights and tables. New York: UNDP, 2015.

Viale, M.L.; Zumárraga, M.J.; Aráujo, F.R.; Zarraga, A.M.; Cataldi, A.A.; Romano, M.I.; Bigi, F. La genómica de las micobacterias. Revue Scientifique et Technique - Office International des Épizooties, v. 35, 2016, p. 215-240.

Zhang, Y., Zhang, F., Li, X., Baller, J.A., Qi, Y., Starker, C.G., Bogdanove, A.J., and Voytas, D.F. (2013). Transcription activator-like effector nucleases enable efficient plant genome engineering. Plant Physiology 161, 20–27.

Section 5. Increasing Efficiency of Food Systems Chains

ABAG, 2015. Logística e competitividade do agronegócio brasileiro. SP: ABAG, 260p

Buainain, A.M. Alguns condicionantes do novo padrão de acumulação da agricultura brasileira. In Buainain, Alves, Silveira e Navarro (Editores Técnicos). O mundo rural no Brasil do século 21: a formação de um novo padrão agrário e agrícola. Brasília, DF: Embrapa, 2014, 211-240p, 1182 p.

Oliveira, A. L.R. A logística do agronegócio: para além do "apagão logístico". In Buainain, Alves, Silveira, e Navarro (Editores Técnicos). O mundo rural no Brasil do século 21: a formação de um novo padrão agrário e agrícola. Brasilia, DF: Embrapa, 2014, 337-370 p,1182íp.

Veira Filho, J.E. e Gasques, J.G. Agricultura, transformação produtiva e sustentabilidade. Brasília, DF: IPEA, 2016, 391p.

Section 6. Health Considerations

ABIEC - Associação Brasileira das Indústrias Exportadoras de Carne. Exportações Brasileiras de Carne Bovina. Janeiro a Dezembro de 2015. Disponível em: http:llwww.abiec.com.br/downloadlrelatorio-anual-2015.pdf. Acesso em 12 dez. 2016.

BRASIL (2016). Secretária de Vigilância em Saúde. Surtos de Doenças Transmitidas por Alimentos no Brasil. Disponível em: http://portalsaude.saude.gov.brlimages/pdfJ20161junho/08/Apresenta--o-SurtosDTA-2016.pdf>. Acesso em: 12 dez. 2016.

Claro, R.M. et al. Unhealthy food consumption related to chronic noncommunicable diseases in Brazil: National Health Survey, 2013. Epidemiol. Serv. Saúde, Brasília, 24 (2), abr-jun 2015.

Ministério da Saúde (BR). Secretaria de Atenção à Saúde. Departamento de Atenção Básica. Guia alimentar para a população brasileira: promovendo a alimentação saudável. 2. ed. Brasília: Ministério da Saúde; 2014.Ministério da Saúde (BR). Secretaria de Vigilância em Saúde. Departamento de Análise de Situação de Saúde. Plano de ações estratégicas para o enfrentamento das Doenças Crônicas Não Transmissíveis (DCNT) no Brasil 2011-2022. Brasília: Ministério da Saúde; 2011.

Nutti, M. R., Carvalho, J.L.V. de, Progress of Biofortification in Brazil. In: Reunião de biofortificação no Brasil, 5. p. 242-246, 2015, São Paulo. Anais. Brasília, DF: Embrapa, 2015. T515.

OIE – Organização Mundial de Sanidade Animal (2016). Estatus de los países membros respecto de la encefalopatia espongiforme bovia. Resolucion No. 20 (84th Sesión General de la Asamblea Mundial, mayo de 2016). Disponível em http://www.oie.int/es/sanidad-animal-en-el-mundo/estatus-sanitario-oficial/eeb/estatus-sanotario-oficiall Acesso em 12 dez. 2016.

Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. Int J Obes Relat Metab Disord [Internet]. 2004 Nov [cited 2015 Jan 8];28(Suppl 3):S2-S9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15543214

Ruel, M. T., Alderman, H. Maternal and Child Nutrition Study Group. (2013). Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet, 382(9891): 536-551.

World Health Organization. Diet, nutrition and the prevention of chronic diseases: report of a Joint WHO/FAO Expert Consultation. Geneva: World Health Organization; 2003.

World Health Organization. Integrated prevention of noncommunicable diseases: global strategy on diet, physical activity and health. Geneva: World Health Organization, 2004.

Section 7. Policy Considerations

Embrapa. Visão 2014-2034: o futuro do desenvolvimento tecnológico da agricultura brasileira. Brasília: Embrapa. 2014. 194p.

IBGE. Instituto Brasileiro de Geografia e Estatística. Pesquisa Nacional por Amostra de Domicílios. Segurança alimentar: 2004/2013: Brasil, grandes regiões e unidades da federação. Available at < http://www.ibge.gov.br/home/estatistica/populacao/seguranca_alimentar_2013/default_xls_2013.shtm > Accessed on November 29th, 2016.

Martha Jr., G.B.; Alves, E. Brazil's agriculture modernization and Embrapa. In: Baer, W.; Amann, E.; Azzoni, C. (Eds.) The Oxford Handbook of the Brazilian Economy (forthcoming, 2017).

Martha Jr., G.B.; Pena Júnior, M.A.G.; Marcial, E.C.; Castanheira Neto, F.; Torres, L.A.; Nogueira, V.G.C.; Chervenski, V.M.B.; Silva, G.T.S.; Wosgrau, A.C. Cenários exploratórios para o desenvolvimento tecnológico da agricultura brasileira. Brasília, DF: Embrapa, 2016. 26 p.

Section 8. Further Challenges and Achievements

ASTI, IDB & EMBRAPA. Agricultural R&D Indicators Factsheet, 2006-2013. April 2016.