Brazilian Agriculture in the Bioeconomy
The Vision of the Brazilian Agricultural Research Corporation

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Abstract

Brazil is one of the largest countries in the world, with an extensive surface of continuous land, a large supply of fresh water, abundant solar energy, and a rich biodiversity. The wide range of climatic conditions, from temperate to tropical, together with advanced capacity in technology development, allowed considerable diversification of agricultural systems in the country, which has become one of the world's largest producers of food, feed, fibers and renewable fuels. The substantial modernization of the Brazilian agriculture, observed after the 1970s was a result of a strong government will, translated as coordinated policies that led to increased R&D capacity and increased volume of credit, improved infrastructure, tied to support policies of stock management, improved distribution and commercialization of food and agroindustrial products. These coordinated policies and support mechanisms led to a better allocation of resources, increased productivity, improved product quality and reducing food prices. Responding to increasing concerns over agriculture´s footprint on the natural resource base, the agricultural research system in Brazil has also taken important leaps, in a short period of time, towards development of innovations for increasingly safer and sustainable agricultural systems. Brazil has already set a target to reduce the agricultural sector's carbon dioxide emissions by 4.9 to 6.1 percent by 2020. With its newly-released Agricultural and Livestock Plan 2010-2011, the country launched a Low Carbon Agriculture Program to stimulate agronomic practices that help environmental preservation and productivity enhancement. Mixed farming systems combining crop, livestock and forest production integrated in

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the same area and with efficient use of inputs are also becoming a reality in the Brazilian agricultural scenario. These and many other developments indicate that the Brazilian agriculture is already evolving in sync with the emerging Bioeconomy, an innovative revolution based on the utilization of biological resources and biological processes to sustainably provide goods and services in food and agriculture and across many economic sectors.

Brazilian agriculture in the past 40 years

Brazilian agriculture, after the 1970s, is a story of success. In the past 40 years the country was able to transform its traditional agriculture into a dynamic and competitive agriculture strongly sustained on science. Up to the 1970s production grew on the extensive margin. Thereafter, especially after mid-1980s, productivity was the major factor explaining production growth. Recent studies by Embrapa (Brazilian Agricultural Research Corporation) - the research arm of the Brazilian Ministry of Agriculture, Livestock and Food Supply - revealed that technology already explains almost 70% of the expansion of agricultural production in the country.

In 1970 the production of rice, dry-beans, maize, soybean and wheat totaled 23.4 million tons. The production of these crops increased by almost six-fold by 2013, to 180.7 million tons. Sugarcane production also presented a remarkable growth, increasing from 67.8 million tons to 589 million tons from 1970 to 2013. In this period yield gains responded for over 60% of the production growth, while crop area expansion accounted for less than 40% of the variation. Such a positive path is further reflected in yield growth rates, which increased from 4.4 kg/ha/yr in the 1950 to 1975 period to 60.8 kg/ha/yr thereafter (1975-2013).

The case of meats is equally successful. In the 1970 – 2012 period, the production of beef, pork and poultry soared from 2.7 million tons to 22.3 million tons. As in the case of crops, productivity gains accelerated from mid-1980's onwards. Martha et al. provided an in-depth review of the factors of growth of the Brazilian beef. Productivity responded for less than 30% of the production growth up to 1985. At that time, pasture area expansion was the major factor behind beef production expansion. However, in the past two decades, productivity explained the majority of beef production increase and pasture area expansion contributed with a minor role. Animal performance in Brazilian beef systems increased 130% between 1985 and 2006, significantly contributing to reduce the intensity of methane emissions. Similar trends in productivity and efficiency gains were noted in poultry and pork sectors.

An outstanding benefit to the environmental dimension of sustainability arising from land productivity gains in Brazilian agriculture is the so called land-saving effects, e.g., the area of land left uncultivated due to technological progress that increased the agricultural output per unit area. In the 1950-2013 period, productivity gains resulting from increased technology adoption in crops (rice, dry-beans, maize, soybean, wheat, sugarcane) and beef production supported a land-saving effect of over 600 million hectares. More recently, the sizeable productivity gains in pastoral systems allowed a significant acreage of pasture area to be freed up and thus accommodate the expansion of crops, mainly soybean and sugarcane, effectively minimizing direct and indirect pressures over native ecosystems.

This virtuous growth path in Brazilian agriculture explains the country as a one of the world's top agricultural producers at the same time it maintains 62% of its territory preserved. In the case of the Amazon, recent estimates indicate that around 85% of the biome is preserved. Better governance, an ample array of policies, and an ever-increasing commitment of the private sector in adopting technologies and practices in accordance with sustainability criteria has been decisive in reducing deforestation rates.

In spite of such progress, it is necessary to recognize the need to move even further in the sustainability path and solve localized drawbacks among agricultural production, environment and social claims. Furthermore, in targeting future perspectives for Brazilian agriculture it is clear the multidisciplinary role that agriculture will play in the coming decades and its increasing reliance on knowledge, technologies and innovation.

Brazilian society is increasingly aware of the key role productivity plays in the development process. Thus, we are confident that the virtuous cycle of research, development and innovation (RD&I) in agriculture, that was fundamental in the past 40 years, will be enhanced in the next 20 years, proving the necessary ground for finding successful responses as needed.

In this context, the adoption of more efficient, "resource- and input-saving" technologies in Brazilian agriculture will increase steadily. The Brazilian Government sees low carbon-emission technologies as a top priority for the future. Indeed, the "Low Carbon Emission Agricultural Program - ABC" outstands in the last three annual Brazilian Agricultural and Livestock Plans. ABC Program targets widespread adoption of novel technologies as integrated crop-livestock systems, no-till planting, recovery of degraded areas, planting of commercial forests, biological nitrogen fixation, animal waste treatment. These technologies help to conserve natural resources such as soil, water, forests and biodiversity and deal with global warming adaptation and mitigation issues in agriculture.

In addition, remarkable scientific advances are taking place in various fields of knowledge. Just to cite a few, consider the huge progress being made in genomics, nanotechnology, automation and robotics, and information and communication technology. Taken together, these and other scientific advances, when properly appropriated by the private sector, will engender innovations and boost the development of novel agricultural production systems with more potential to add value and to ensure increased productivity, safer and higher quality food, and other agricultural products and environmental services. Ultimately, in the coming decades the world might expect from Brazilian agriculture innovations that will increase our current ability to understand and respond to present and future risks and challenges in diverse areas of knowledge in tropical and subtropical environments.

In order to make such views a reality it is essential to expand investments in human resources training. Additionally, it is necessary to recognize that no Institution has all the solutions to fully and adequately respond to the challenges and opportunities ahead. This means that agricultural R&D Institutions in Brazil must strengthen partnerships and alliances within and beyond the country's borders. Enhancing cooperation will thus be essential to strengthening a sustainable path for agricultural value chains.

Agricultural Innovation and the Emerging Bioeconomy

Brazil has developed a large and complex agricultural research basis, which is composed of public institutes, universities, private companies and non-governmental organizations. This capacity stands as one of the most comprehensive and most efficient in the tropical belt of the world (Gasques & Conceição, 2001; Pastore & Alves, 1980; Alves, 2010).

Beginning in the 1970s, Brazil improved its structure and capacity substantially, developing a two-tier system of federal- and state-based agencies. This so-called National System for Agricultural Research and Innovation (SNPA) has developed and promoted a wide array of technological innovations that has triggered the expansion of agribusiness over the past four decades. The SNPA is responsible for organizing, coordinating and implementing research that objectively contribute to the development of agriculture, sustainable use and the preservation of natural resources. Implementation of the SNPA concept led to the strengthening of agricultural R&D capacity in Brazil, with improved infrastructure, human capacity, management mechanisms and support policies on a national scale (Beintema et al., 2001).

Embrapa – the Brazilian Agricultural Research Organization - is by far the largest component of the Brazilian SNPA System. A semiautonomous federal agency administered by the Ministry of Agriculture and Food Supply, Embrapa is the largest agricultural R&D agency in Latin America in terms of both staff numbers and expenditure (Pastore & Alves, 1988; Beintema et al., 2001). Embrapa is headquartered in the capital Brasilia and operates research centers throughout the country. The Organization has 46 Research Centres and Service Units, 17 Administrative Units, 6 Virtual Laboratories Abroad (Labex), and 6 Technical Cooperation Projects abroad.

Embrapa has always invested a great deal of effort in foresight (Embrapa, 2003; Lima et al., 2007) strategic planning and improvement of institutional processes (Embrapa, 1988, 1994, 1998, 2004, 2008b). In its 40th birthday, in 2013, Embrapa has announced several institutional innovations aiming to prepare itself to the next 20 years. In a partnership with Consepa (Conselho Nacional dos Sistemas Nacionais de Pesquisa Agropecuária, [National Council of the Agricultural Research System]), with the support from the Ministry of Agriculture, Livestock and Food Supply, and the Ministry of Science, Technology and Innovation, Embrapa launched in April 2013 the project "Alliance for agricultural innovation in Brazil". This initiative, aims at getting more interaction and collaboration in innovation projects at the same time it has the objective of "translating science into practice" more timely, reaching farmers and providing information to overall society more rapidly.

Embrapa's R&D efforts move fast forward in a portfolio/arrangements model prioritizing RD&I actions focusing on important strategic themes to Brazilian society. R&D portfolio and arrangements are further nested into "macro-themes", which provide a strong focus to Embrapa's agenda. For that purpose, and given increasing concerns about the multidisciplinary role that future agriculture

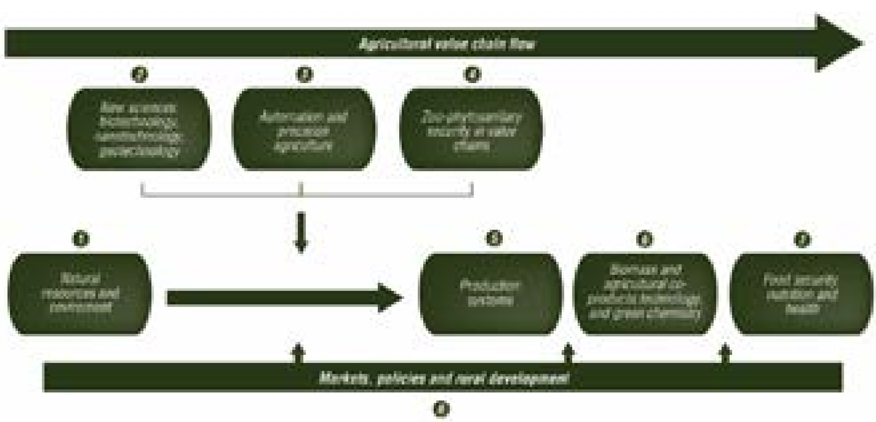

Figure 1. Embrapa's view of the agricultural value chain with elected priority macro-themes.

will play and its increasing reliance on knowledge, technologies and innovation, Embrapa has organized its RD&I strategy (and associated prospective studies) into macro-themes, which are oriented by a value chain approach and strong connection with emerging challenges and opportunities, including the Bioeconomy (Figure 1).

One important novelty in the foresight process, tightly linked to its RD&I activities, is the establishment of Embrapa's Strategic Intelligence System (Agropensa), stablished in December 2012. The Agropensa system aims at producing and disseminating knowledge and information to support the elaboration of research, development and innovation strategies for Embrapa and partner institutions, and to inform decision making in the public and private sectors. Agropensa also works towards mapping and supporting the organization, integration and dissemination of an agricultural information database. With this approach, it captures and prospects trends, identifies possible futures, and hence elaborates scenarios that can allow Brazilian agriculture to be better prepared to face potential challenges and opportunities, with a focus on RD&I.

Figure 2 presents the components of the Agropensa System. The Observatory of Studies and Trends has the role of capturing, prospecting and monitoring relevant trends and ideas in Brazil and abroad. The Analysis and Studies component targets the study of priority themes defined by Embrapa's Strategy Management Committee, with the purpose of pinpointing bottlenecks, opportunities and possible courses of action. Finally, the Strategies component aims at transforming previously generated information into effective decision making by Embrapa, contributing to the design of plans and agendas and supporting the elaboration of public policy.

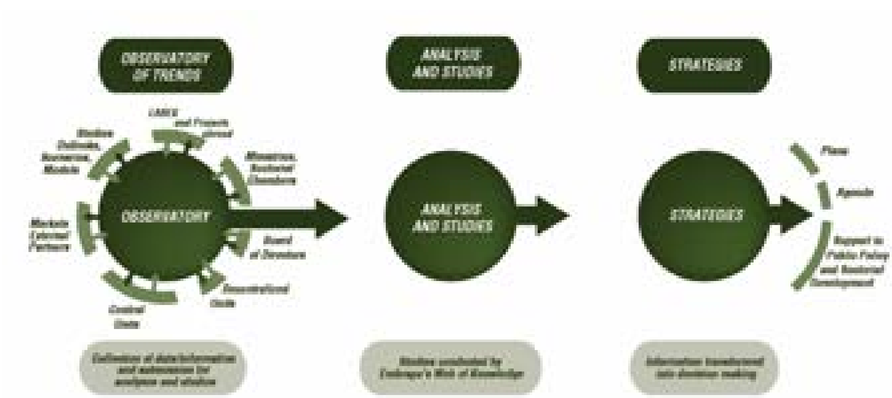

Figure 2. Components of the Agropensa System.

What to expect in the next 20 years?

Embrapa's Strategic Intelligence System (Agropensa) has developed a series of studies and analysis of the challenges ahead which are summarized in the document "Vision 2014-2034 the future of the technological development of the Brazilian agriculture" (Embrapa, 2014). This scenario and foresight effort indicated that the challenges ahead are enormous. Agriculture will have to concentrate, at the same time, in two important fronts: competitiveness and sustainability. More efficient technologies will be necessary to supply the needs of food to Brazilian society, besides the production of exportable surpluses to the world, thus fulfilling expectations of the country contribution to food and nutritional security, globally. Technological advances will have to facilitate preservation of natural resources such as soil, water, forests and biodiversity. Add to that attention to global warming and its potential effects on agricultural production. More research is needed to mitigate effects of extreme weather events and to allow adaptation to new presumptive scenarios of biotic and abiotic stress intensification, as well as energy insecutiry.

Despite the scale of the challenges, one must also recognize that the technological progress in several fronts is impressive, increasing chances of successful response. Scientific revolutions are happening in various fields of knowledge, from biology with genomics, from physics and chemistry with nanotechnology, from information technology and communication, with numerous innovations that increase our ability to respond to risks and challenges. In recent years, biology has produced tremendous advances in the study of genomes, which allow us to broaden our understanding of complex mechanisms in plants, animals and microorganisms. From such advances will arise innovations to agricultural diversification, specialization and value addition, besides increased productivity, safety and quality to food and other agricultural products.

Innovations in the fields of information technology and communications, remote sensing, advanced instrumentation, automation and robotics indicate that precision agriculture will emerge as common practice in agriculture in the near future. These tools and processes will allow smarter use of our natural resource base, ensuring more productivity, efficiency and sustainability in production systems. Nanotechnology, with innovations in the scale of the billionth of the meter, also promises to revolutionize the development of multiple products, processes and instruments. Advanced sensors will enable the monitoring of production systems with great precision, new materials and processes will allow development of machines and equipment more efficient, accurate and durable.

All these innovations will have enormous implications for the future of agribusiness. In order to benefit from them, and to remain competitive, countries will need to invest in training of human resources and sophistication of processes, methods and instrumentation. Information and communication technologies also promise to further revolutionize methods of managing agricultural production, access to markets, logistics and the relationship between producers and consumers. New Information and communication technologies have also the potential to change behavior, requiring increasing attention to consumer demands and to perceptions of society in relation to agriculture.

Genetic Diversity, Agriculture and the Emerging Bioeconomy

The emerging Bioeconomy will become a source of many creative strategies to mobilize genetic diversity to help agriculture face the challenges ahead. More attention to research in genetic resources and crop breeding is paramount, to expand the variability base and to mobilize new biological functions capable to help agriculture fulfill its part in the pursuit of a sustainable future. Here are some challenges the agricultural research community will have to face, to assure that agricultural biodiversity will be efficiently mobilized to help the world achieve and maintain food security in the future:

Strengthening Crop Breeding Capacity: The production of new, more adapted and productive crop varieties, a result of genetic improvement, is one of the main contributions of agricultural research to humanity. Plant breeders have been able to adapt plants to a wide range of agricultural areas around the world, to cropland with marked differences in soil and climate, intense biotic and abiotic stresses and diversified technology usage patterns. Thus, capacity to develop genetic innovations in the form of improved crop cultivars will continue to be fundamental to all countries, especially in the face of increasing challenges posed by climate change and stress intensification. Strengthening crop breeding capacity through efficient research in plant genetics and biotechnology will ensure that agriculture maintains the ability to respond to problems that may jeopardize food and nutritional security in the future.

Sustainable Use of Water: Despite being the sector that already consumes most water, irrigated agriculture tends to grow in the future, due to climate change, which leads to more extreme weather events – especially droughts. Also, the need to increase agricultural productivity to meet the demands of a growing population will increase concerns and conflicts related to competitive uses of water. Therefore, a major challenge for the future will be the optimization of water use by agriculture in order to reduce the pressure on this finite resource and release water for other purposes. Innovations to rationalize the use of water and to avoid or reduce its waste will be critical to meet the growing demand for food, with minimal environmental impacts. Access to genetic variability and to biotechnological tools and processes to empower crop breeding will be increasingly essential to make crops increasingly efficient in the use of water.

More Effective Protection of Agriculture: One of the critical challenges for food production is the movement of exotic organisms or invasive species from one region to another, depending on trade, transport and tourism. Globalization of pests leads to displacement of organisms from one region to another, intentionally or not, with significant potential for economic, environmental and social impacts. This reality has led to the intensification of control practices and, in many cases, the justification for unfair market protection. Strong emphasis on technological innovation is critical to meet the diverse demands of importing countries and response to rigid compliance standards that are consolidated internationally. Countries will have to develop production systems sustained in sanitary practices consistent with internationally accepted patterns of quality and safety assurance for their agricultural products. Availability of genetic resources and breeding research on plant resistance to pests will play increasingly prominent role in the defense of agriculture around the world.

Increasing Safety and Efficiency of Agricultural Inputs: There is no doubt that agriculture will be pressed to seek alternatives or substitutes for inputs of high environmental impact and/or derived from non-renewable sources. Many conventional inputs, like pesticides and fertilizers, contribute to rising costs in food production, may have deleterious impacts on the environment and directly or indirectly affect global warming processes. It is, therefore, necessary the development of alternative and safer sources of nutrients, such as nitrogen fixation by bacteria or bio-release of phosphorus and potassium from non-conventional mineral sources. Also, the research in genetic resources can contribute to identify variability to efficiency of nutrient use by plants, particularly those nutrients that are scarce or have large potential impact on the environment. Crop breeding and biotechnology have the capacity to mobilize this variability to change plant resistance to pests and nutrient use efficiency, with high potential of impact in the sustainability of agriculture.

Linking Food, Nutrition and Health: The concerted integration of food, nutrition and health strategies appears to be inevitable, due to demographic changes (increase in the average age of the population) and the exhaustion of health and social security systems, even in developed countries. The gradual change to a disease prevention paradigm will require food more suited to the needs of consumers (biofortified with vitamins, minerals and high quality protein), adapted to demographic changes (increasingly elderly population) and capable of boosting performance in various capacities (physical, intellectual, etc.). Genetic improvement will have to focus on the development of food with high nutritional and functional density, high quality, producing minimal waste and enabling manufacture at low cost with high productivity.

Sustainable Intensification of Land Use: Technologies capable of allowing increased and more sustainable use of the natural resource base will receive more attention in the future. In many parts to the world agricultural land has been degraded and abandoned. If recovered, these are the ideal areas for expansion of agriculture, livestock and planted forest, without the need for further deforestation. It makes more sense to recover degraded areas than to open forested areas to farming. Integrating production systems, like crop-livestock, and crop-livestock-forest are already proven possibilities for land recovery in many countries, especially in the tropical belt of the world. Such technological innovations may allow configurations of low carbon agriculture and dissemination of sustainable and more resilient farming practices. The research on genetic resources and breeding will contribute to development of plants and animal breeds better adapted to low carbon agricultural systems based on crop-livestock and crop-livestock-forest integration.

Agriculture Interfacing with Green Industries

The theme "Green Economy" is frequent in discussions related to the future of sustainable development. Biomass and biorefineries tend to play a key role in response to global climate change, to meet the demands for sustainable energy, chemicals and new bio-based materials. There is no denying to the emergence of a value chain around biomass, which will create significant opportunities for new business and a new technological and industrial paradigm based on low carbon.

The growth of the bio-based economy can generate multiple opportunities for economic growth and creation of new jobs, including in rural areas. And one can foresee a number of technical, strategic and commercial challenges that must be addressed before such green industries flourish. Many countries in the world, including Brazil, are able to leverage the economic potential and sustainability of new bio-industries, both to enhance clean energy production, and to develop a new and thriving renewable chemicals industry. Agricultural biodiversity and research on genetic resources, breeding and biotechnology will be essential to support this new development paradigm, which has great potential to contribute to a more sustainable future.

Conclusion

The agriculture of the future will be impacted by concepts, methods and multi-functionality far beyond the conventional. Technological standards of the global agriculture are now being changed by the introduction of new technologies resulting from very recent advances in scientific knowledge. Sustained in such advances and in tune with the emerging green economy, agriculture should be guided by a new set of features and requirements, which will conform the technology standards of the future.

The challenges highlighted in this chapter indicate that changing agriculture and food production in ways that ensure improved sustainability and a healthier and more nutritious food supply involve the increased use of advanced technologies, with special emphasis in creative uses of genetic diversity, which will conform the development of the Bioeconomy. Despite the scale of the challenges, one must also recognize that the technological progress in several fronts is impressive, increasing chances of successful response.

Impressive scientific revolutions are happening in various fields of knowledge - in biology with genomics, in physics and chemistry with nanotechnology, in information and communication technology, with innovations that increase our ability to respond to risks and challenges. In recent years, biology has produced tremendous advances, which allow us to broaden our understanding of complex mechanisms in plants, animals and microorganisms. From such advances will arise innovations to agricultural diversification, specialization and value aggregation, besides increased productivity, safety and quality of food essential to assure a more sustainable future for humanity.

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