SUMMARY OF THE FORESIGHT STUDY:

# THE SOUTHERN CONE IN A NEW ERA OF TECHNOLOGICAL DEVELOPMENT

***Megatrends, critical uncertainties and key questions about the future of the agri-food and agricultural system in the Southern Cone***

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*Megatrends, critical uncertainties and key questions about the future of the agri-food and agricultural system in the Southern Cone*


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# Prologue

The Cooperative Program for the Development of Agri-food and Agricultural Technology in the Southern Cone (in Spanish, PROCISUR) —created in 1980 with the support of the BID (Interamerican Bank of Development) — is a collaborative project conducted by the National Institute of Agricultural Research (in Spanish, "INIA") in Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay along with the Inter-American Institute for Cooperation on Agriculture (in Spanish, IICA).

In 2015, in the context of a new Mid-term Plan, PROCISUR embraced the challenge of developing new strategies to advance a new regional agenda to profit from the opportunities the agri-food and agricultural sector offer according to future trends.

Therefore, PROCISUR promoted changes in terms of strategy, tactics and operations, introducing guidelines to direct its actions in terms of strategic planning. The goal of the managerial strategy followed by the Institution was to promote the development of its members and of PROCISUR itself in order to strengthen national and regional systems of innovation.

Thus, in 2017, PROCISUR created a network of strategic intelligence and prospective to support the Program's planning process and its member institutions, incorporating a regional approach into each national strategy.

The network was specifically created to train professionals in each INIA and stakeholders working in the field of strategic intelligence and prospective resources for them to exchange knowledges and practices; to provide training courses delivered by external and internal experts, and conduct prospective research studies in the Region applying the scenarios technique.

In 2017 and 2018, the main actors in the global system of science, technology and innovation applied to the agricultural and agri-food industry joined us in the execution of a prospective research study called "The Southern Cone Faced to a Crucial Point for Global Technological Development" using the so-called "learning by doing" method. The study was coordinated by the Prospective and Public Policies Institute from INTA, Argentina (National Institute of Agricultural Technology) and EMBRAPA's Agropensa from Brazil (Brazilian Company for Agricultural Research).

The following document details the main megatrends, critical uncertainties and key questions about the future of the agri-food and agricultural system in the Southern Cone we have identified and consider a priority in our research study. We hope this publication may serve as a significant contribution to decision-makers to set the agenda and strengthen the regional strategy for sustainable innovation and development in the Southern Cone.

**Cecilia Gianoni**
Executive Secretary
PROCISUR

# Introduction

Part of the strategy followed by PROCISUR (**Cooperative Program for the Development of Agri-food and Agricultural Technology in the Southern Cone**) includes, among other actions, the execution of a regional prospective study on the agricultural, agri-food and agro-industrial sector **with focus in science, technology and innovation**, an initiative approved by the Commission directing this Program.

**The study was performed using the so-called "learning by doing" method** where the different teams within the **Prospective and Public Policies Institute** from INTA (National Institute of Agricultural Technology) and EMBRAPA's Agropensa from Brazil (Brazilian Company for Agricultural Research) were responsible for designing the exercise to be performed and the instruments to be used to train a group of professionals selected by each INIA (National Institute of Agricultural Research) in the Southern Cone in order to start building a prospective network and develop a strategic intelligence system within PROCISUR.

The core objectives of the initiative were:

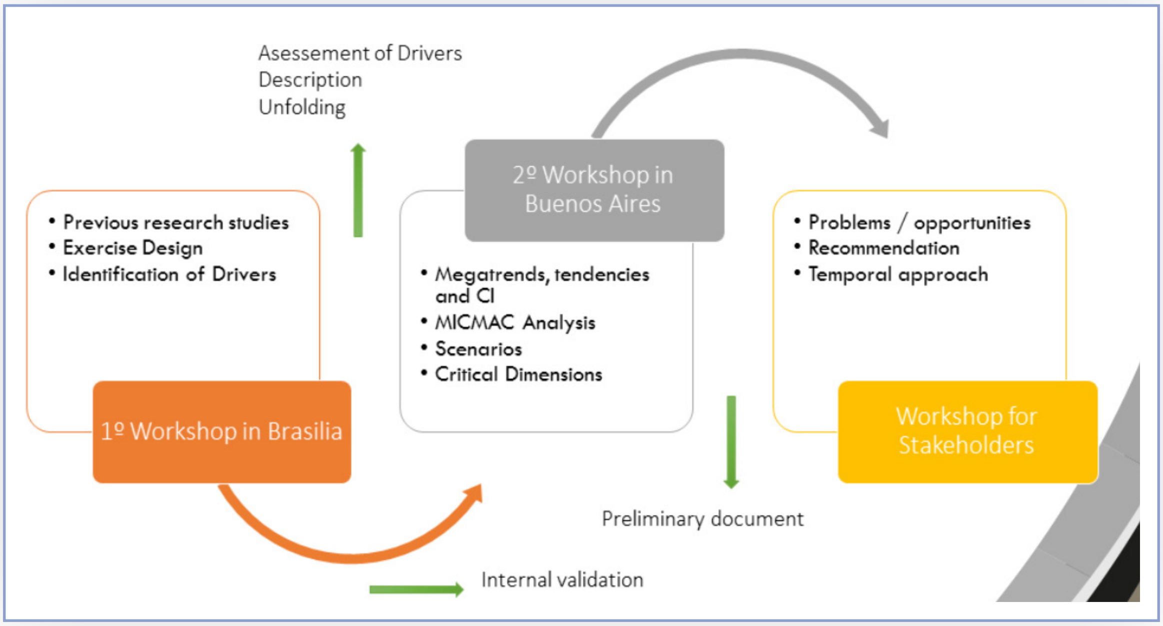
- To develop and strengthen the skills and capabilities we need in order to **incorporate the dimension of futures** into the organization and management of the scientific and technological policies applied in the region.
- Raise decision makers' and stakeholders' awareness of the foresight methodology and policy implications
- To provide materials to elaborate a new PROCISUR Mid-Term Plan (MTP) 2019-2022.

In order to meet the goals set forth, three workshops on strategic intelligence and foresight were conducted. This implied the delivery of more than 50 hours of training aimed at professionals including each INIA team in the Southern Cone along with other stakeholders selected. The **first workshop** was held in Brasilia in July 2017 where a group of experts described the research conducted and the challenges faced in terms of research, development and innovation (R&D&i) in regard to the scientific and technological system used in China, the United States, France, and the Southern Cone. Furthermore, training sessions were offered to learn about the methodology of prospective analysis. Additionally, participants were encouraged to work on the identification of the main **drivers** (factors for change) that determine the dynamics of the agricultural and agri-food systems in the Southern Cone. In the timespan that ranges from the first to the second workshop, participants made a brief characterization of the drivers identified analyzing their potential evolution.

The **second workshop** was held in Buenos Aires in October 2017, where those drivers were transformed into megatrends and critical uncertainties. Additionally, different scenarios were prototyped in order to illustrate how the so-called foresight method works and the risks and chances for the Southern Cone considering the different settings foresighted. In November 2017, the results of the whole process were presented before PROCISUR'S Committee.

Finally, in August 2018, a third workshop was held, again in Buenos Aires, with the participation of external stakeholders from each INIA. Megatrends and critical uncertainties were discussed, identifying the main problems and opportunities for the Region that could pose some relevance for each INIA in order to develop materials to elaborate PROCISUR's MTP 2019-2022. Graphic 1 provides a schematic explanation of the process[1].

1 Full basic statistic information, the records of the workshops performed and the complete description of the different megatrends and critical uncertainties selected with the corresponding references are Available at the full version document entitled "The Southern Cone Faced to a Crucial Point for Global Technological Development". This document shall be available upon request. The full version is only in Spanish. Contact information: Diego Gauna (gauna.diego@inta.gob.ar) or PROCISUR's Executive Secretary (sejecutiva@procisur.org.uy)

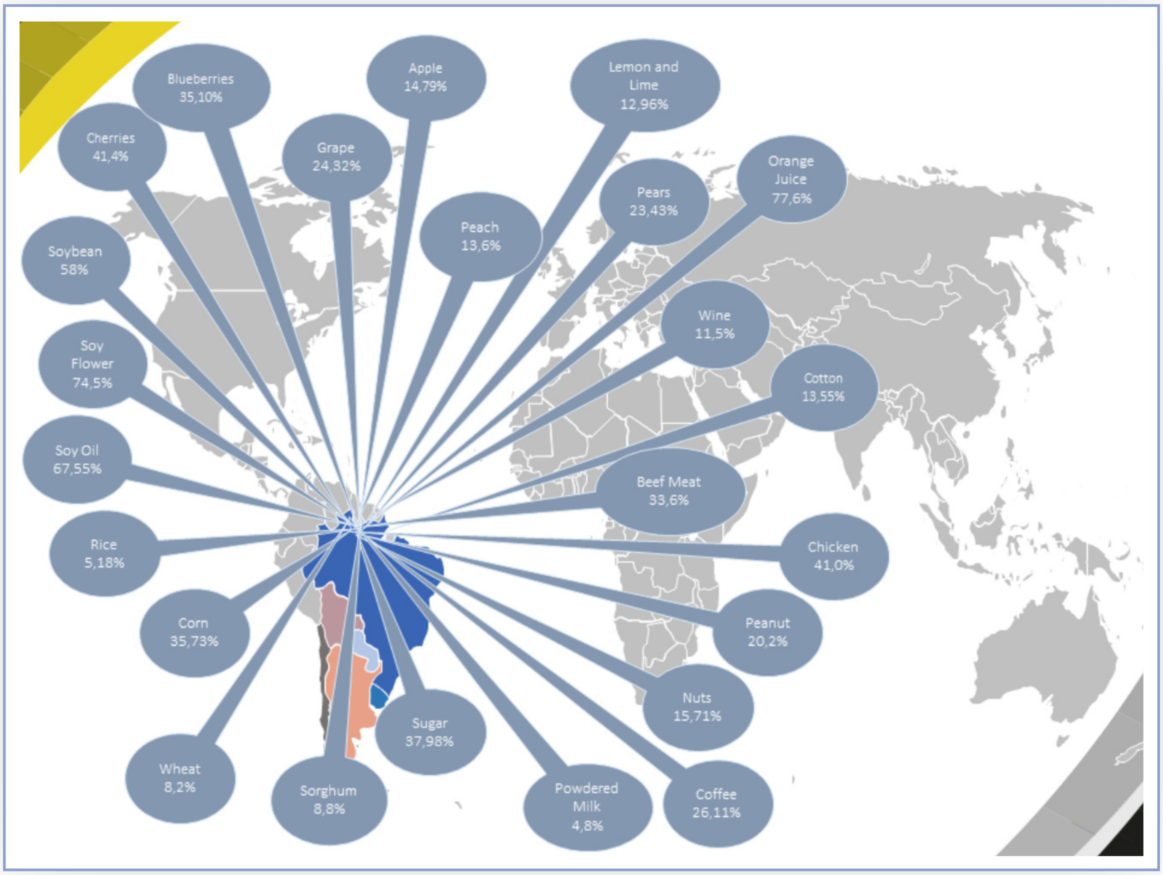



**Graphic 1.** Scheme of the Method used in the Exercise Performed

# The Southern Cone as an Agri-food and Agricultural Power

The Southern Cone Region has a central role in the global agri-food market. This centrality is confirmed not only by the dynamics of production and exports in the Region and its contribution to global food security, but also by the supply and quality of its natural resources and the richness of its biodiversity. Below, we provide some figures and markers that illustrate the current importance of the Southern Cone in world agriculture:

- In terms of **area**, the Southern Cone represents 46.3% of the global planted surface of soybeans; 12.4% of the global planted surface of corn; 4.4% of the global planted surface of sorghum, and 3.9% of the global planted surface of wheat, while in terms of **global production**, the Southern Cone represents 50.8% of soybean production, 11.6% of wheat production, 10.2% of sorghum production, and 3.4% of wheat production. Moreover, the Southern Cone represents 35.4% of the oranges, 20.2% of the limes and lemons, 7.9% of the grapes, and 6.5% of the cherries produced in the world. As regards cattle production, the Southern Cone owns 24% of the chicken and 22.4% of the bovine global production. With respect to the production of liquid biofuels, the Southern Cone accounts for 18.6% of bio-diesel and 16% of bio-ethanol global production.
- The Southern Cone has a **surplus in the production of agricultural and food commodities** with a commercial surplus for the agricultural and agri-food sector estimated in US$107,000 million, which is almost six times greater to the value registered in 2000. If we compare agricultural exports in the Southern Cone in the past decades with the values registered now, we still notice the processing of agricultural products is low. In line with past decades, agricultural exports in the Southern Cone **lack processing**. The Region concentrates exports of agricultural and agri-food products **in a reduced number of countries**. Asia currently represents 42.5%, 53.72%, 35.2%, 22.6% and 37.0% of the agricultural products exported respectively by Argentina, Brazil, Chile, Paraguay and Uruguay (where China is the most important partner).
- Graphic 2 shows the percentage of exports from agricultural and agri-food centers in the Southern Cone compared to total world exports.
- Countries in the Southern Cone lead world exports of **flour and soybean oil, biodiesel and lemon juice** (Argentina); **fresh grapes, blueberries, cherries and salmon** (Chile); and **coffee, sugar, bovine meat, chicken meat, soybeans and orange juice** (Brazil).
- The Southern Cone has a bit more than five million family farm units, which represents 83.9% of the total agricultural exports in the region. Furthermore, family agriculture generates more than 50% of all job positions in the agricultural sector in the Southern Cone, though the percentage varies significantly depending on the country.
- The Southern Cone has 133 million hectares of arable land, which represents 9.4% of all land in the world. Ninety percent of arable land is concentrated in Brazil (81 millions) and Argentina (39 millions).
- South America has one of **the largest reserves of freshwater in the planet** which, according to estimates, accounts for a third of the whole reserves of freshwater in the world. Brazil has 12% of the reserve of freshwater in the world and concentrates 53% of all freshwater reserves found in South America. Furthermore, forest biomass in South America is equivalent to a quarter of the whole forest biomass in the world.



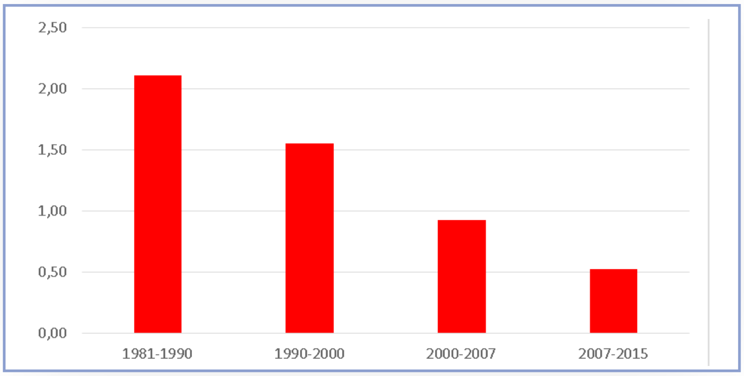

**Graphic 2.** Position of the Region in terms of World Exports.
Source: Own elaboration based on USDA's data (2018).

- The Southern Cone is one of the regions with the largest global biodiversity. Brazil is the country with the largest biodiversity in the world accounting for 15 to 20% of the whole biologic biodiversity at a global scale. Biodiversity hotspots in the Southern Cone are in "The Cerrado" (Brazil), The Atlantic Forest (Brazil, Argentina and Paraguay), The Winter Rainfall-Valdivian Forests (Argentina and Chile) and part of The Tropical Andes.
- Each INIA in the Southern Cone has more than **5,100 researchers** (with a PhD in 60% of the cases), **535 research points** (centers, stations and laboratories) and **165 germplasm banks**.

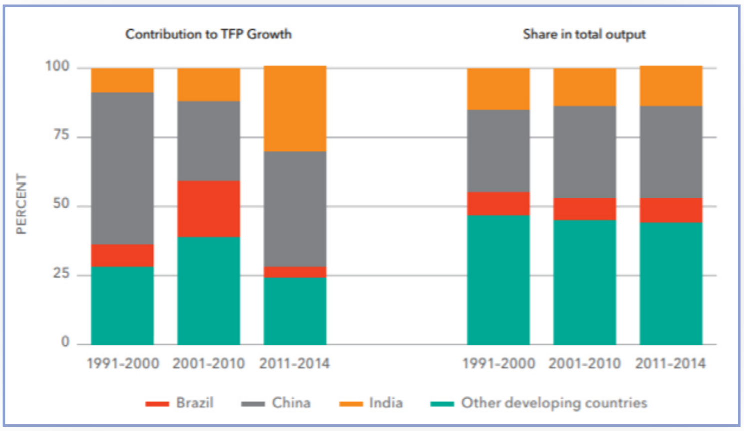
# The Southern Cone Faced to a Crucial Point for Global Technological Development

Scientific and technological advances in the physical, biological and digital world are transforming agricultural production systems, management and nutrition in the globe. Countries in the Southern Cone —a region with a historical surplus of agricultural production, food commodities and reserves— have to rethink the traditional organization models used for science and innovation in order to meet the future needs posed by an increasingly complex and uncertain environment. At the core of this new environment we find the concept of science and technology convergence, a new approach towards problem solving that comprises different knowledges, resources and techniques from different fields (life sciences, computing sciences, mathematics, physics and types of engineering), thus creating a new, comprehensive approach to face the scientific and social challenges we find at the interface of multiple dimensions (for example, climate change, changes in the use of soil and biodiversity loss).

The emergence of new technologies is particularly important in a context of deceleration of the agricultural TFP (total factor productivity) growth rate in the United States (USA), an increase in TFP global growth in emerging countries (especially China, India and Brazil) and an increasing production expansion due to productivity earnings. Graphics 3, 4 and 5 illustrate these trends:

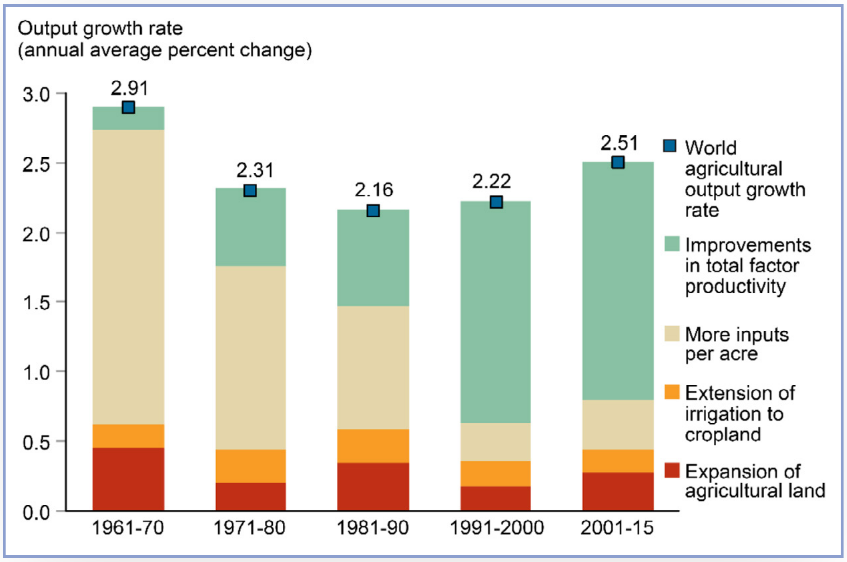



**Graphic 3.** Average Annual TFP Growth Rate in Agriculture – The United States. Source: Self-compiled information based on USDA's data (2018).




**Graphic 4.** Major Drivers of TFP Growth

Source: IFPRI (2018).




**Graphic 5.** Sources for Growth in Global Agricultural Output, 1961-2015

Source: USDA, World Agricultural Production Database

The situation in the Southern Cone is, in character, heterogeneous. While Argentina's situation is similar to that of the USA, Uruguay and Brazil show a sustained average annual TFP growth since the early 1990s. In the case of Chile and Paraguay, the TFP growth accelerated from 2002-2007 and then experienced a deceleration in the last decade.

Below, we enumerate and analyze some of the emerging technologies with the largest potential for the agricultural and agri-food sector:

## NEW BREEDING TECHNIQUES

New breeding techniques (NBTs) are based on advances in biotechnology, molecular biology and DNA sequencing that can be used in a variety of species. Within this cluster of techniques, genome editing has emerged with more strength thanks to the newer ZFN, TALEN and CRISPR methods. **Genome editing** is a **genetic engineering technique** that consists in the insertion, deletion or replacement of a DNA pieces from the genome of any organism, while the CRISPR-Cas9 technique has created a revolution to fully understand how genetic modifications should be done in animals and plants.

In the field of agriculture, the technique promises to be a significant achievement to improve food quality traits including appearance, resistance to plagues and diseases, postharvest life and drought tolerance, among other uses. In terms of livestock agriculture, genome editing has a potential to generate livestock that may be resistant to disease or with a capacity to produce food with specific characteristics. Nowadays, only a few crops are genetically altered for commercialization, but most genetically engineered plants are grown in the United States where we find corn modified for altered starch composition, canola resistant to *sulfonylurea* herbicide, soybeans lower in unsaturated fatty acid and edible mushrooms that remain white colored after being processed. Nevertheless, the amount of research studies published in scientific publications about the use of CRISPR and the number of patents for products that resort to this technology have increased so sharply that we can also expect the amount of genetically altered products in the market is also going to increase in the following years.

At present, there is a hot debate around the regulation of this type of techniques. The American position holds up that products derived from genome editing processes cannot be considered genetically modified organisms (GMOs) and thus they should not be subject to the expensive regulatory process used for GMOs before being placed on the market. This stance has triggered off a strong investment in NBT in the United States. On the other hand, in July 2018, the Court of Justice of the European Union (EU) ruled that all products obtained by gene editing should follow the same regulatory procedure used for GMOs based on the argument that only mutagenesis techniques that have been used long enough and have a long safety record are exempt from the obligations imposed on GMOs. The position in the Southern Cone —considering the country members that have already taken a stance— is similar to that of the US. According to the Declaration of the Ministers of Agriculture members of the **CAS (Southern Agricultural Council)** on the occasion of the CAS XXXV Regular Meeting, genome editing is strategic for the Southern Cone where products derived from genome editing processes should not be excluded from international trade unless the decision may be founded on scientific grounds.

## DIGITAL AGRICULTURE

Digital agriculture can be conceptualized as a new phase in the evolution of **precision agriculture** which, in general terms, combines the intensive use of information and computing technologies. Though some digital technologies have a long tradition in the field of agriculture, the latest technological advances have determined an expansion in the service digital technologies can provide in terms of reach, scale and immediacy. In the era of digital agriculture, agricultural producers administer resources based on an **individualized, coordinated approach** with optimized, real-time, hyper-connected production systems. The range of digital technologies that can be potentially applied to production systems is quite broad going from simple platforms and applications to advances in robotics, artificial intelligence, remote sensing, sensors, the internet of things and big data.

Digital agriculture, more than a revolution in itself, is a resource to optimize existing technologies, increase the efficiency of production systems, reduce agriculture's environmental impact, and a driver for **sustainable farming systems**. The great suitability of the Southern Region to incorporate digital technologies into the agricultural sector is portrayed by the expansion of the **Agtech Ecosystem** in the last five years. Nevertheless, the Region still faces multiple challenges including questions related data use and property, the development of models to analyze the complexity and heterogeneity data collection, and the necessary infrastructure to manage integrated data platforms.

## ARTIFICIAL INTELLIGENCE (AI)

AI is focused on the general question of creating intelligent machines. Within the different branches of IA, machine learning (ML) is one of the areas with a higher potential to be used in the agricultural sector. ML is based on the idea that systems can learn from data, identify patterns, make predictions and decisions almost without human intervention. The most promising commercial applications of ML can be found in advances based on deep learning. Advances in the field of AI are strategically relevant for any country. In the last two years, more than fifteen countries (including the United States, Japan, South Korea and China) and different regional blocs (EU and the Nordic-Baltic Region) have created national strategies to develop AI. As of the date of publication of this document, no state in the Southern Cone has developed a national strategy, though some countries have already acknowledged the importance of the task.

The application of AI in the global agricultural sector is still limited, though it can potentially cause a great impact in research and development as in other activities performed in the field. At present, some applications are under development for **early disease identification** and damage assessment, for weed control by means of more effective herbicides, for the harvesting of fruits by means of robots, for the analysis of satellite information, for soil health, for the genetic enhancement of animals and plants, for livestock monitoring, for the use of **predictive models** to improve agronomic decision-making and for testing crops with nutritional deficiencies, among other relevant uses.

## ROBOTICS

The use of robots in agriculture has been lately increasing due to the advances in computer sciences and engineering and the shortage of labor. These advances have determined a significant reduction in production costs and in the use of robots due to improvements in their functionality. The progress of robotics in the agricultural field has determined a growing automatization of **production processes**, a trend already present in the foundation of modern agriculture. This does not necessarily imply that labor in the agricultural and agri-food sector shall be substantially reduced due to the advancement of robotics, since new technologies may also stimulate labor demand with a different level of qualification in related services. For example, robots can reduce the demand for manual labor, but simultaneously **increase labor the demand for tasks related to programming and design**.

The use of robots in agriculture is growing, mostly for essential production tasks. Some examples, with different levels of market maturity, are: the use of robots for weed control **to reduce the use of herbicides**; the use of robots with sensors that can detect plagues and diseases with higher precision **reducing the need of pesticides**; the use of robots with a potential to reduce the environmental impact of livestock farming; the use of robots with a potential for **aquaculture**; the use of robots for plant **phenotyping** and the creation of **dairy farms operated by robots**, among others.

Advances in digital agriculture, artificial intelligence and robotics, along with the application of solutions using the internet of things (IoT) in agriculture converge in a new concept that is penetrating into national and international debates about the future of agriculture: the concept of **intelligent agriculture, agriculture 4.0 or smart digital farming.**

## TECHNOLOGIES FOR THE ELABORATION OF SYNTHETIC FOOD

Research to produce synthetic food has a long history that begins with the initiatives conducted by the National Aeronautics and Space Administration (NASA) in the United States in the 1960s and 1970s to elaborate food for astronauts up to present initiatives to produce synthetic meat, not derived from an animal. The creation of these initiatives results from the environmental impact of current production systems and the consolidation of movements against animal slaughter, aspects that have determined the rise of a new scientific field called **cellular agriculture**. The greatest breakthrough in cellular agriculture is **synthetic, cultivated or "in vitro" meat**. This innovation is a product of the advances of regenerative medicine and tissue engineering. At present, the United States, Israel and Europe have start-ups financed by private investors, philanthropists and important corporations in the meat industry to experiment on the "synthetic" production of cow, chicken, turkey and fish meat.

The advancement of cellular agriculture has awakened much controversy. Some of the issues are whether synthetic meat can be called “meat”, as those in the synthetic meat industry call it, or if synthetic meat should be given a different name, like meat derived from simple muscle tissue. The National Cattlemen Association in the United States and other countries interested in livestock production are now demanding for a special label in case synthetic products eventually reach the retail market.

Another interesting example is the use of synthetic milk, free from hormones and antibiotics, apt for vegans and produced with the modern methods of biotechnology. Also, in the last years, the most disruptive technique under research is the production of proteins generated only from water, bacteria, carbon dioxide, and electricity. This technology in evolution would allow for a much more efficient food production that is free from the influence of environmental conditions.

## BLOCKCHAIN

Blockchain is a type of DLT (Distributed Ledger Technologies) where all the members of a group can record the transactions performed by means of a decentralized database held on networked computers avoiding the use of a physical device or single database. All transactions need to be almost immune to hacking and be validated by some consensus mechanism for the purpose of transparency and safety. Blockchain gained popularity for being the technology that underpinned the cryptocurrencies. We are talking about a technology that is emerging, potentially disruptive, transversal, rapidly evolving and difficult to regulate that creates great uncertainty about the impact it may cause and the multiple challenges that massive implementation implies.

In the field of food and agriculture, we are expecting significant improvements in product traceability across the industry’ value chain. In particular, the implementation of the blockchain technology is expected to increase the level of goods with credence attributes (credence goods) and reduce the amount of intermediaries in the commercial chain. For example, blockchain technology makes it possible to trace if a productive process met all the ethical commercial practices for the benefit of local producers. Furthermore, multinational companies are already using the blockchain technology to check food security in order to reduce contamination in food. Other possible applications include the trading of commodities and food in standardized markets and to promote transparency in the market of working lands.

Finally, other promising advances for the future of the industry include research on plant, soils and animal microbiomes; technologies used to advance **agriculture in close environments** and the application of synthetic biology to produce second and third generation bioproducts.

In this context, the smart farming concept has gained more significance within the agriculture industry, mainly because the use of this technology results in efficient, sustainable food production under the right conditions with remote control over a smaller portion of land.

# Megatrends

Megatrends reflect long-term social, technological, cultural, economic, environmental and institutional changes that, once established in the system, have a long-lasting and significant effect shaping different spheres of government and society. The megatrends we have identified in our research are detailed in Table 1.

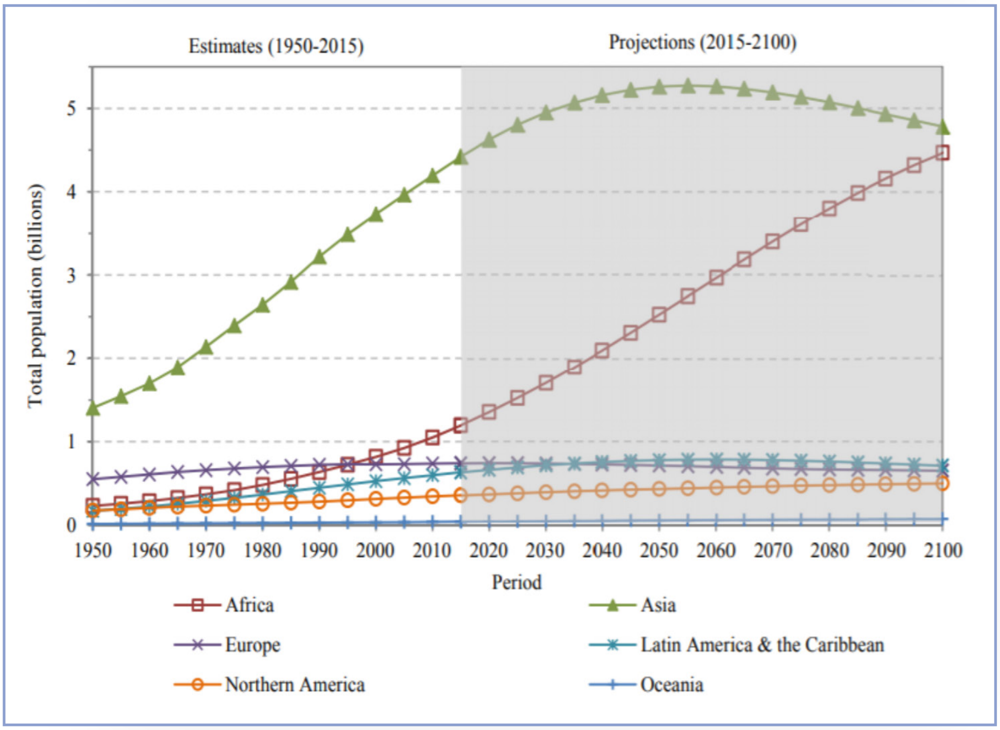
**Table 1.** Megatrends and their Main Characteristics

| Megatrends | Main Characteristics |
|---|---|
| Changes in the demographic and dynamic processes of urbanization | • Population growth mostly driven by Asia and Africa.<br>• Growth in urbanization processes<br>• The importance of the rural-urban interface<br>• Population aging |
| Closing the gap between developed and emerging countries | • Emerging countries are now getting a growing proportion of the global gross domestic product (GDP)<br>• A significant growth of the middle class in the world.<br>• A shift in diet. |
| Shift of technological capabilities towards emerging countries | • Emerging countries have more participation in global R&D actions (China, India, Brazil and South Africa).<br>• Scientific and technological platforms in the United States and Europe are losing relative weight in global innovation processes.<br>• Private investments in R&D are gaining ground in the global R&D arena. |
| New habits and preferences in consumers | • New benefits of food associated with health or with the environment and nature of production process are gaining more ground amongst consumers.<br>• Acquisition of value with greater market segmentation.<br>• Friction and/or convergence associated with the concept of what is “natural” and “artificial”.<br>• People gain more influence in proposing an agenda for the public and private agri-food sector. |

| | |
|---|---|
| Climate change | • Global agenda to fight against climate change (CC)<br>• Manage funding against CC.<br>• R&D to apply technologies against CC. |
| Transformations in agri-food value chains. | • Agri-food value chains are increasingly more integrated into the global market.<br>• High market concentration of supplies used in agriculture<br>• Growth of Latin American companies with a potential for expansion in other Latin countries.<br>• Chinese growing investment in Latin America. |
| Growing demand for world market access. | • Higher compliance standards related to food quality and security<br>• From "product standards" to "standards for processes".<br>• Standards are increasing their scope of application.<br>• The growing importance of private standards. |
| New trends to finance and organize science and innovation | • Less influence of traditional public investment in research studies.<br>• Consolidation of the open science and open innovation approach.<br>• Significant growth of start-ups in innovation processes<br>• Expansion of innovation models organized in clusters, scientific and technological areas and districts. |
| New paradigms, approaches and/or models used in agri-food production | • Bioeconomy and circular economy.<br>• Sustainable intensification.<br>• Ecological and agro-ecological intensification<br>• Sustainable food systems. |
| Concentration and foreignization of the land market | • Multinational corporations and governments purchase large portions of land in Asia and Africa<br>• New forms to concentrate production. |

## DEMOGRAPHIC CHANGES AND DYNAMICS OF URBANIZATION PROCESSES

According to the latest report on world population prospects developed by the United Nations, by 2050 world population is expected to reach 9772 million inhabitants which represents world population will increase by 29.4% compared to 2017. Prospects in terms of population growth differ considerably among regions. Africa and Asia account for a bit more than 90% of the growth estimated by 2100 according to the medium-variant projection.




**Graphic 6.** Estimated and Projected Population Growth

Source: World Population Prospects: The 2017 Revision. United Nations

Population growth will determine a growth in urbanization. By 2050, the percentage of people living in urban areas is to increase from 55% to 68%. Additionally, megacities are also going to grow in number: it is estimated that, by 2030, there will be 43 cities with more than 10 million inhabitants, most of them in developing regions. Faced to the dichotomy of statistics when comparing urban to rural populations, we fail to visualize the growing economic, social and political interdependence between big cities and rural communities and the challenges faced by the agri-food production at the urban-rural interface.

The aging of population will be sharper in the following years, especially due to a decrease in fertility rates and an increase in life expectancy. According to projections, by 2050, population aged 60 years and over is expected to double. Similarly, by 2050, the population aged above 60 in Latin America will represent 25% of the total population in the world, whereas today the percentage is 12%. Aging is a megatrend that that is likely to have an impact on the different spheres of actions of governments and corporations creating profound disruption in political and economic systems.

## CLOSING THE GAP BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

In the last decades, we have observed **a gradual change in world economy's center** that moved from the economies of The Group of Seven (G7) countries to the economies of emerging nations, more specifically Asian economies. In 1980, the group of developed economies represented 63% of the world GDP, while in 2017 these economies only reached 41%. Projections towards 2050 foresee the process will follow the same trend at a lower rate compared with previous decades, thus closing the economic gap in relative terms since some important disparities will be maintained as in the case of the absolute level of per capita GDP. **China, the United States and India** shall be, in this order, the economies with the greatest GDP by 2050

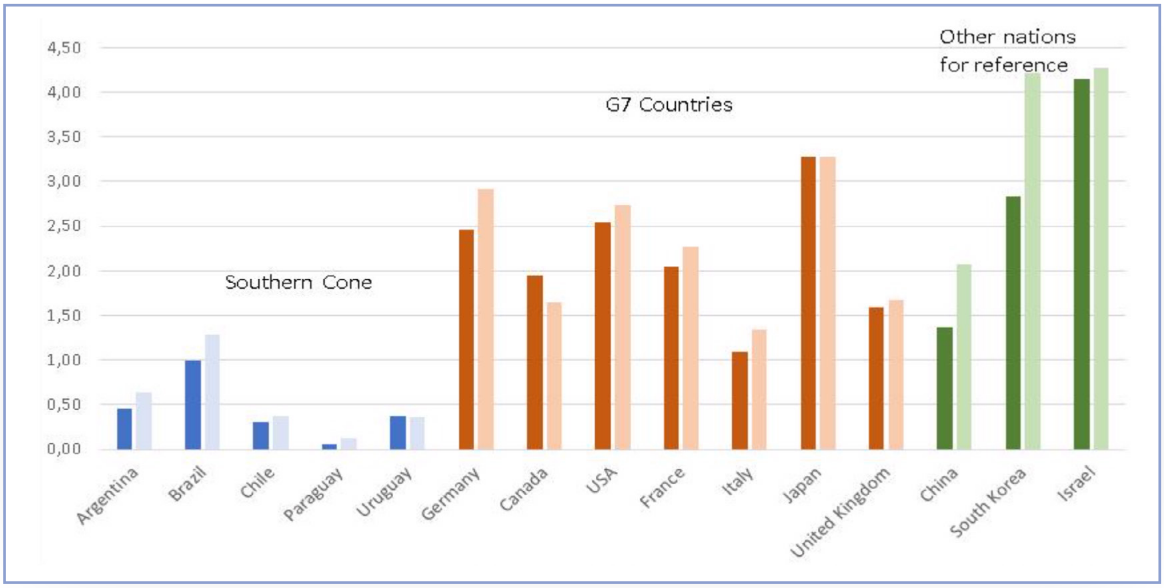
Prospects in population and economic growth are also related to an expansion of the global middle class. In 1950, only 10% of the world population lived in middle class homes, a percentage that reached almost 40% in 2016 (**3,200 million people**) and, according to estimates, by 2050 the percentage shall reach 60% (**5,800 million people**). The rise of global middle class is creating a sustained increase in the demand of animal protein. We expect the increase in the middle income of the emerging classes from Asia will accelerate the shift in diet we have observed in the last decades which implies **a decrease in the relative consumption of grain and pulse along with a greater relative consumption of meat**. According to estimates, meat production is projected to double by 2050 and move from today's production of 273 million tons (including bovine meat, chicken meat and pork meat) to 445 million tons by 2050.

## MOVING TECHNOLOGICAL CAPABILITIES TO EMERGING COUNTRIES

Though the United States is still the world leading country in science and technology, its involvement in global initiatives has been decreasing lately due to the growth of emerging Asian countries. China's investments in science and technology have been growing at an annual 18% rate since 2000 to become the second largest investor in the world after the United States. In terms of GDP, we observe sharp difference between emerging Asian countries, The Group of Seven (G7) countries and countries in the Southern Cone (Graphic 7).

Furthermore, investments in venture capital for the commercialization of emerging technologies in China have increased from a 5% of total investments in 2013 to a 27% in 2016 (the United States owns more than 50% of those investments). Moreover, in 2016 China concentrated almost 43% of all patent applications filed worldwide, followed by the United States (19%) and Japan (10%), though most applications filed were for domestic use. It is important to consider that, though emerging countries have a great potential for technological expansion, penetration rates and the dissemination of their new technologies in the market are still comparatively low.

This agricultural industry has witnessed a similar process. According to the latest data we can use to establish a comparison (from 2011), almost 55% of investments in the agricultural industry for R&D come from high-income countries, while in 1980 the percentage was 69%. On the other




**Graphic 7.** Investment in R&D compared to GDP (2006-2015). Source: Own elaboration based on data obtained by RICYT (The Network for Science and Technology Indicators –Ibero-American and Inter-American–). Dark and light shades in bars compare investments in 2006 and 2015, respectively.

hand, the group of middle-income countries, led by China, Brazil and India, were responsible for 43% of investments (with a quota of 29% in 1980). Besides, **the growing influence of the private sector in R&D within the agricultural global industry** should also be pointed out. Historically, most research studies performed in agri-food and agriculture were typically conducted by universities and governmental agencies. However, according to most recent data, an average of 52.5% of all research studies on plant breeding, computing, fertilizers, pesticides and food technologies conducted in high-income countries were commissioned to private companies (in 1980, the percentage was 42%).

As regards current trends in higher education, 4.7 million students graduate in science, technology, engineering, and mathematics (STEM Education) in China every year (more than 50% of the total amount of graduates) with 2.6 million graduates in India. In relation to postgraduate studies, the United States is the country with the largest amount of graduates with PhDs in STEM (40,000 per year) followed by China (34,000) and Germany (15,000).

## NEW CONSUMER HABITS AND PREFERENCES

Though price, secure consumption and taste are still some of the main drivers that shape consumer preferences, other issues including transparency in the value chain, **fair distribution** of benefits in each chain, **animal welfare**, the **origin** of the product, to what extent the product is **"natural"**, whether the product consumed is **healthy and nutritious**, among other aspects.

Furthermore, international surveys have shown the generation is another influential factor: ***millennials*** assign greater relative importance to a product that is natural and/or organic, to environmental impact and to animal welfare in contrast to former generations. Changes in consumer preferences —that provide a chance to increase **segmentation in the agri-food industry**— have also reshaped agri-food value chains.

Changes in consumer preferences can be exemplified with the consolidation of the market of organic products, mostly in fruits and vegetables. At present, the United States, Germany and France account for 50% of the organic food market with sales for US$75,000 million. Future prospects indicate a sustained growth in demand with an average annual growth rate estimated in 20% by 2025.

The **spread of social media and digital platforms** has determined radical changes in the relationship between food producing companies and consumers since those with more information access share their experiences assessing the products they use according to trade expanding their decision power before buying a product. As regards the influence of consumers in the public agenda, we can consider the growing amount of requirements for **food labelling**. Although voluntary food labelling has been typically used as a strategy to differentiate a product from the rest, compulsory labelling for food containing GMOs or any substance that requires a claim (if the product contains, for example, saturated fats, sugar, or sodium) is becoming increasingly more frequent. Food labelling regulation in Chile is a paradigmatic case in the Southern Cone with promising preliminary results.

## CLIMATE CHANGE (CC)

One urgent challenge in the following years will be to reshape current food production systems in order to **build resilience** to the impact of climate change (CC). According to international reports, in the last years CC has affected all natural and human systems in every continent and ocean where changes in precipitation patterns or ice melting are altering the hydrological system so the impact of CC on crop yields has been rather negative in general. Most countries in the world are developing plans to mitigate CC and adapt to it considering the most important industries in their economies.

The impact of CC in production systems is widely studied nowadays. Some estimates indicate that crop production will decline by 17% by 2050 due to CC, a number that could be reduced to 11% if we consider economic players' endogenous response. As regards countries in Latin America and the Caribbean (LAC), according to a report issued in 2016 by Food and Agriculture Organization of the United Nations (FAO), the United Nations Economic Commission for Latin America and the Caribbean (UNECLAC) and the Latin American Integration Association (in Spanish, ALADI), CC is going to impact negatively in crop yields jeopardizing food security in the region, especially in Bolivia, Ecuador, El Salvador, Honduras, Nicaragua, and Paraguay, countries that could suffer the greatest impact. CC is expected to alter affect areas that are optimal for the cultivation of crops including coffee, sugar cane, potatoes and corn, among others (Graphic 8). Another area of interest for researchers has to do with the value of ecosystem services and their importance to regulate the effect of CC.


**Graphic 8.** Latin America and the Caribbean: CC Impacts expected for 2050. Source: United Nations Environment Program (UNEP)/ Economic Commission for Latin America and the Caribbean (ECLAC), Vital Climate Change Graphics in LAC. Special Edition for CP16/CP-RP 6, Mexico, Bogotá, 2010. Reproduced in CELAC's Plan "Food Security, Nutrition and Hunger Eradication 2025: Elements for Debate and Regional Cooperation", CEPAL-ALADI-FAO (2016).

In LAC, the creation of public policies to mitigate the impact of CC and adapt to it, cannot be divorced from **a long-term vision** of the region (2030-2050); we need to acknowledge the paradox of time (the fact we need to act immediately, even when the impact of CC will be seen in the long term); we have to consider **the double asymmetry** of the impact (countries typically making hardly any contribution to mitigate CC are generally more vulnerable and the poorest sectors within them receive the greatest impact) and prioritize the implementation of **strategies to achieve adaptation**.

Finally, we observe the international community is reorienting the allocation of resources to support projects to promote adaptation, conservation and/or mitigation of ecosystems making greater investment in R&D of climate technologies. In 2017, the six most important MDBs (multilateral development banks) in the world granted US$35,200 million to research on climate change —the largest amount in seven years— which represents a 28% increase compared to the year before. As regards the funding of R&D of climate technologies, we can see inversions are concentrated in the United States, Japan and Germany and that most them arise from the public sector. Though investments have increased considerably since the beginning of the century, they still represent a low proportion of global investments in R&D.

## TRANSFORMATION OF AGRI-FOOD VALUE CHAINS

Agri-food value chains in the Southern Cone are currently undergoing structural transformations triggered off by a new global and regional context. **Firstly,** we observe **a trend towards the integration of Latin America into global value chains** (GVCs). In GVCs, corporations are carrying out a process of de-verticalization whole stages in the production process in order to concentrate on the activities they need to control. Integration into GVCs in far from neutral and it is an issue that introduces multiple debates over the effects of integration in the business, the industry and the distribution of benefits amongst participants.

Secondly, we also observe **the advance of transnational corporations created with capital flow from Latin America**, or the so-called *Multilatinas*. The rise of "*multilatinas*" can be checked in the increasing flow of direct investments abroad they have done over 2004-2013. The four largest agricultural corporations from Latin America nowadays are from Brazil.

**Thirdly,** investments in LAC coming from China continue on the rise. Chinese corporations have made 303 business operations in LAC over 2001-2016, which represents a significant growth compared to the amount of operations registered during the period 2010-2016. As regards investments based on the country of destination, Brazil got 48.3% of investments, followed by Peru with 10.9%, Argentina with 9.3% and Chile with 2.9%. The **consequences of the penetration of China in the Southern Cone**, either by means of investments in natural resources or in corporations that produce agri-food or energy, has sparked debate about the effect of this penetration in the degree of processing of exports, employment, sustainability in the use of natural resources and food sovereignty in the region.

In the fourth place, we also notice **a growing concentration of agricultural supplies in the market**. The six great stakeholders in the global market of seeds and agrochemicals will be reduced to four in the short term. It is worth noting that, from 2000 to 2015, the percentage of seeds sold by the four main stakeholders in the United States grew with an increase from 60% to 85% and the 51% to 76% in corn and soybean sales, respectively.

The effect of mergers in innovation efforts is not linear because efforts in R&D are conducted with low levels of concentration, thus causing an effect that has started to be counterbalanced by a strategy of protection of current developments provided that the level of concentration is augmented.

Finally, the insertion of the agri-food and agricultural industry into global markets implies meeting standards constantly growing in complexity in terms of **food security, traceability** and **ecological footprint.**

## GROWING DEMANDS FOR MARKET ACCESS

Access to the global food market is growingly complex and it is driven both by the domestic policies of countries with a long history of protection of the primary sector and by the new demands society makes in terms of economic, social and cultural sustainability of production systems. The generalized reduction of fares in the world has determined higher non-tariff barriers to trade (NTBs), i.e. barriers of restriction through mechanisms other than the imposition of tariffs. NTBs may take the form of quotas, non-automatic licensing, domestic subsidies, the application of sanitary and phytosanitary measures (SPM), technical barriers to trade (TBT) and regulatory requirements according to law and the rules of origin in the field of intellectual property. In this document, we shall concentrate our analysis SPM and TBT due to the particular importance they have in the trade of agricultural products.

SPM need to rest on a solid scientific basis since these measures are intended to protect human and animal health y secure the preservation of vegetables prevent the penetration of products that may be hazardous for people's health for they contain harmful physical, chemical or biological properties. The regulation of SPMs includes labelling and packaging requirements, exposure limits to hazardous substances, importation bans to prevent pests, hygiene requirements, fumigation processes, and food irradiation, among other measures. It is important to mention that in the Eleventh Ministerial Conference of the World Trade Organization (WTO), 17 countries (including all the countries in the Southern Cone) signed a declaration to acknowledge the importance sanitary measures (**particularly pesticide maximum residue levels**) in **world sources on pesticide regulation and in the scientific risk assessment of pesticides** in order to avoid unfair barriers in international trade.

On the other hand, TBTs comprise measures related to tolerance to prohibited substances, requirements for transportation, labelling and packaging, quality standards, and compliance to conformity assessment procedures (tests, certifications, seals, inspections, traceability and history of the item, among others).

If we have to analyze the impact of both measures, SPM and TBT, we observe the number of environmental requirements applied to commercial products has been increasing in the last years. Some indicators like the **carbon footprint and the water footprint** have gained more relevance. Nowadays, some countries are already implementing new labelling to include these indicators in the products they import and, based on current perspectives, the trend is going to consolidate even more in the future.

In spite public regulations concerning trade in the food market typically focus on **quality and safety**, private standards have increased considerably over the last decades. Though private standards are not mandatory, in practice they function as effective restrictions to commerce since, in most cases, private standards are more difficult to meet compared to public regulation. Some examples include voluntary standards, codes and certification schemes aimed at retail companies, collective national standards and/or multilateral standards.

## NEW TRENDS TO FINANCE AND ORGANIZE SCIENCE AND INNOVATION

Political, social and cultural changes have determined a new examination of the traditional models for management and organization of science and innovation. Though the debate is not new, it has excited more controversy around the challenges posed by the sustainability of a national system of innovation. The analysis of this megatrend only touches upon some aspects of the debate since a complete, comprehensive analysis is clearly beyond our scope of analysis.

**Firstly,** job positions **with less stability** at universities in the United States are currently gaining more relative weight. They encourage the conservation of current production lines instead of promoting the exploration of new areas since financing actions are secured by means of grants. **Secondly**, international funding entities are promoting **transdisciplinary research and networking**. Thirdly, philanthropists have increased their presence in innovation market making investments in start-ups with a potential to develop disruptive technologies to solve essential human problems. Furthermore, there are new, modern ways of financing that are becoming more popular, as in the case of **crowdfunding**. In its simpler version, crowdfunding involves entrepreneurs make an open call, essentially through the Internet using online platforms, in order to summon investors, donors, philanthropists or anyone interested in financing a project where different participants contribute with a small amount. Another important trend has to do with the use of instruments created to increase **collaboration** between the different actors involved in the innovation ecosystem. These instruments were created to provide a solution for market failures that affect business innovation by promoting the use of strategic partnerships that contribute to internalize knowledge spillover; a coordinated use of complimentary assets and the sharing of the technology risk involved when agents from the private sector invest in innovation. For example, some of these instruments are technology or innovation consortiums, which are characterized for cross cooperation between different firms by means of formal agreements in order to make collaborative investments in R&D for the purpose of advancing scientific and technological knowledge and then apply such knowledge in the creation of new and better products and processes.

Furthermore, **open innovation models** are gradually being incorporated into the innovation system. Initially thought to be used by large corporations with a business focus, these models combine the internal knowledge found within the organization with external knowledge to promote R&D projects based on market needs. The paradigm of open innovation has three essential components: people, allies or partners and **collective intelligence**. The open innovation field is still in an early phase of development and provides broad space to gain the attention of scholars, trainees and decision-makers in politics to start working in the field. The transition towards a new phase in open innovation called **Open Innovation 2.0** implies approaching any investment in R&D&i as an instrument to drive structural change based in the creation of **innovation networks** and in the co-construction of knowledge.

Finally, we have observed the creation and consolidation of new scientific and technology centers and districts focused on innovation. The so-called **research parks** were created by universities, private developers and the State that in collaboration designed and built clusters of laboratories and corporations to engage scientists with entrepreneurial spirit in order to increase research commercialization. At present, estimates indicate there are more than 400 scientific parks while more than 150 are located in the United States. Innovation districts are another phase in the evolution of scientific parks since their creation responds to the growing value of proximity and the density of the new economy of knowledge. Innovation districts are geographical areas where leading anchor institutions and corporations contact start-ups working as business incubators and accelerators. Innovation districts came into existence as a response to the weaknesses of innovation parks: rows of isolated buildings in the suburbs that can only be accessed that provide no life quality, no job interaction, no living conditions or space for recreation.

## NEW PRODUCTION PARADIGMS, APPROACHES AND/OR MODELS

The need to diversify the traditional energy mix, the current effect of modern agriculture in the environment, and the new challenges to food security have led to the introduction of new paradigms with an increasing influence on topics for debate discussed both at the national and international level. The most salient topics discussed include bioeconomy, sustainable intensification in a broad sense (which includes conventional sustainable, ecological and agro-ecological intensification) and the FSA (Food Systems Approach).

**Bioeconomy** has gained prominence in the last decade, as developed countries, rich in natural resources, began to incorporate bioeconomy as an essential part of their strategic planning. The main concept implies the progressive substitution of products derived from fossil fuels for renewable resources of biological origin in order to mitigate losses in value chains and **thus make a more efficient use of biomass for the production of food and energy**. Bioeconomy is an instrument for the development of resilient territories. It adopts different forms according to the different features in each country or region.

Nowadays, the main countries in the world have developed well-defined national bioeconomy strategies (Germany since 2010, Finland since 2014, and France since 2017, for example). At present, countries in the Southern Cone with the largest degree of institutionality are Brazil and Argentina, but they still lack a national strategy framed by a strategic plan for development. The Southern Cone has great potential to develop strategies for development based in bioeconomy since the region has one of the largest **photosynthetic platforms** in the world with a great variety of biological resources available.

Additionally, in the last decades, we have noticed general concern for developing a sustainable **intensification of agricultural production** both in economic, environmental and social terms. At present, we can say there are three predominant models which have been deeply discussed in academic papers that co-exist together: the conventional model of **sustainable intensification** (SI), the model of **ecological intensification** (EI) and the model of **agro-ecological intensification** (AEI).

The model of **SI** predominates in the world with wide acceptance in forums and well-welcomed by international organisms (CGIAR, FAO, and SDSN among others), governments, donors, national and transnational corporations in the agro-business, institutions working on R&D&i and the scientific community in general. According to the model of SI, science, innovation and technological developments play a central role because scientific research is considered a fertile ground for innovations that may improve food production in quality and quantity. We are faced to a relatively open concept since the model does not support any particular vision, method or technology for agricultural production. Instead, the model is more focused on the ends than in the means to attain sustainability.

On the other hand, **EI** and **AEI** are characterized by an **ecosystemic approach** where they propose an intelligent use of the functionalities and services of ecosystems. These two models question the suitability of the conventional SI model because it cannot be sustained both in the social dimension and from the thermodynamic and ecological/eco-efficient point of view. Besides, the SI model fails to preserve food safety around the globe and contributes to biodiversity loss. Research studies on EI and AEI require changes in disciplinary principles. The differences between the concept of EI and AEI are subtle but relevant in political and institutional debates. The definitions of the AEI model explicitly **incorporate the social and cultural dimensions** and emphasize the importance of using local agricultural knowledge to define innovation strategies and highlight the **systems approach** to agriculture.

Finally, action plans developed by the international community have incorporated **the food systems (FS) approach** as a response to new challenges in food security in the 21st century, the prevalence of undernutrition, micronutrient deficiencies, and the overweight and obesity epidemic. In spite of the advances observed in the 20th century, it is estimated that 800 million people still live in a state of **undernutrition** accounting for 45% of deaths in children under five.

Micronutrient deficiencies imply the inadequate intake of vitamins and minerals, specifically vitamin A, iron and iodine. Finally, in the last years, the prevalence of obesity and overweight has increased at an alarming rate: it is estimated that, at present, 1,900 million people are overweight of which 400 million are obese. Overweight and obesity are associated with an increase in heart disease, diabetes and cancer which, in all, are estimated to cause more deaths than undernutrition. This approach is closely linked to concept of "**One Health**" promoted by the World Health Organization (WHO), the FAO and the OIE (The World Organization for Animal Health) where they analyze different aspects involved at the human-animal-ecosystem interface.

The FS approach highlights the importance of the diet as a link between food systems on health and nutrition outcomes and the influence of **food environments** to encourage consumers to make sustainable and healthy choices. Moreover the FS approach also considers the impact of production and food systems in the economic, environmental and social dimension. The concept of food environments includes not only the aspect of proximity to food or the economic aspect but also **food advertising and channels for promotion and dissemination of information** related to **food quality and safety**.

## CONCENTRATION AND FOREIGNIZATION OF THE LAND MARKET

Rural and urban-rural zones are currently suffering a number of structural changes that may have a profound influence on living conditions and on rural zones with a potential for production in the future. At present, one of the most salient changes comprises two different but related processes: **the concentration and the foreignization of lands in rural zones.**

The concentration of rural zones in the market is a process with a long history that changed its dynamics after the food crisis in 2008. The biggest producers in the EU, representing 2.7% of all producers there, are currently in control of 50% of all arable land. Europe is concerned about this concentration process for the impact it may have on agriculture (increasing prices or rent expenses, thus complicating land access for small and mid-size producers) and on society, especially as regards to the administration of natural resources.

In African and Asian countries, the process was characterized by the purchase of large portions of land to be used for food production. These acquisitions also involved the participation of foreign governments or private corporations related to them, thus the concentration process came along with a process of foreignization under the premise of securing land and natural resources in case the food crisis continued. By the end of 2008, estimates indicated that Middle-East countries (Qatar, Saudi Arabia, and Kuwait) and countries from East Asia controlled more than 7 million hectares of arable land in foreign countries.

On the other hand, in the Southern Cone, the process of concentration and foreignization of land has acquired multiple forms and a new dynamism that goes beyond the concept of property or acquisition in a strict sense. Sowing pools, agricultural investment funds and the consolidation of mega-corporations in the agricultural industry are examples of these innovative forms of concentration that have emerged in the last decade.

The difference between what happened in the Southern Cone compared to Asia and Africa stems from the fact a large proportion of the land market is in private hands, the key role of domestic elites, the importance of Latin multinationals in the market, the limited significance of investments of the Gulf Countries, China, South Korea and India and most importantly, due to the fact concentration takes place in countries where the state is not weak or unsuccessful, as it happens in Africa.

The phenomena of concentration and foreignization determine the impossibility to reverse current tendencies in migration from the country to the cities, but at the same time cause the expelling of small agricultural producers that lose their land (either for selling or renting them), their jobs or even their autonomy as producers as processes for food production get more and more concentrated. Thus, rural population is under risk and there are a number of social and territorial conflicts (around the possession and use of resources) of different nature and degree. An alternative approach could be to think of these processes as an opportunity to start producing in agricultural areas with high potential by means of large investments that work as a parachute to be used in complex scenarios threatening global food safety.

## Critical Uncertainties and Key Questions about the Future of the Agri-Food and Agricultural System

Critical uncertainties (CU) comprise factors, tendencies and processes able to dynamize the object of any system under research that once identified help to foresee alternative futures. In other words, they are **drivers of change with a high degree of uncertainty** about their future evolution. Megatrends and critical uncertainties in combination orient us to start imagining future scenarios for innovation in the agricultural and agri-food sector in the Southern Cone, to do research on possible threats and opportunities, and to identify main difficulties and challenges. Chart 2 shows the CU we have identified and how they are expected to unfold in the future. The unfolding expected is not based on probability. Instead, the idea is to anticipate the evolution of the different main uncertainties listed here which are essential for the system we are analyzing[2]. Read our full research paper for a brief description of the rationale behind our hypothesis.

**Chart 2.** Critical uncertainties and how some of them could possibly unfold in the future

| Critical Uncertainty | Hyphotesis |
|---|---|
| The evolution of global economy | Growth crisis in emerging Asian countries |
| | The gap is closed in a context of global development |
| | Global stagnation and constant state of crisis |
| The evolution of global geopolitics | Bipolar balance of world power focused in the United States and China |
| | Towards a new multipolar world |
| Opening international food markets | Global protectionism and frequent trade wars |
| | Bilateral trade agreements gain more weight |
| | Multilateralism is strengthened |
| Regulation of new technologies in the countries of the Southern Cone | Adaptation to international regulation with no differentiation |
| | Adaptation to international regulation with differentiation |
| | Development of a regulatory framework of its own |
| Africa in the international food market | Africa makes no progress in terms of production |
| | Incremental progress of productivity in Africa |

2 A brief description of the rationale behind our hypothesis can be found in the full document (only Spanish version).

| | |
|---|---|
| **The evolution of productivity in the agricultural sector.** | **Stagnation** |
| | **Trend growth** |
| | **New revolution triggered off by emerging technologies** |
| **The evolution of renewable energies** | **Progressive substitution of fossil fuel** |
| | **Disruption in the energy market** |
| **Public perception of science and technology** | **Personal feelings or beliefs gain ground in scientific and technological debates.** |
| | **Personal feelings and beliefs fail to gain ground in scientific and technological debates.** |

# Key Questions about the Future

The research study conducted so far led us to identify a number of megatrends and CU that determine the future of the agricultural and agri-food sector in the Southern Cone with focus on science, technology and innovation. These megatrends and CUs have been discussed and analyzed in depth in a Workshop for external stakeholders that concluded with an exercise done to identify the main problems and opportunities setting priorities based on the dimension of the problem in the region and the opportunity it represents and how relevant it is considering the activity of each INIA[3].

Before concluding this phase within our research study —and considering this work results from a process of collective building that is still in progress— we would like to list a number of key questions that may eventually be used as a catalyst in future debates in each INIA, in IICA and in PROCISUR:

1. How can the Southern Cone build a regional vision to develop and shift from its current status as a **global food reserve** to become **a global bio-economic power** in the future?
2. To what extent science and technology institutions in the Southern Cone are prepared to make a technology leap in the production of agricultural and food commodities and bioproducts to meet the challenges posed by a new era characterized by **technological convergence**?
3. What **skills or abilities** do institutions working on science, technology and technical cooperation in the Southern Cone need to develop on order to be in tune with new global scenarios?
4. How should current **models for agricultural science and innovation** in the Southern Cone be reshaped to be resilient to a new technological scenario?
5. How should **instruments and programs for regional cooperation** be structured in order to build the necessary synergies to develop a regional agenda for R&D&i in the sector with a forward-looking approach?
6. What features regional cooperation programs are supposed to have in order to build a shared vision that may be less vulnerable to political changes in the countries of the Southern Cone?
7. How could the interaction between the environment and agriculture be strengthened so that the process of expansion in the agricultural sector may be compatible with a **sustainable food system approach**?
8. To what extent the dynamics of **social and cultural changes** in agriculture can accelerate or delay the leading role of the Southern Cone in the world agri-food market and how this may affect the agenda for R&D&i in the region?
9. How can PROCISUR members get ready for a new era considering the impact of **digital natives** entering into the workplace?

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3 Details on the Workshop can be found in full document (only in Spanish Version).

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