ISSN 1992-4933

ComunIICA ONLINE

Year 7 | January - July 2011

Inter-American Institute for Cooperation on Agriculture

New realities, new paradigms:

the new agricultural revolution

Economic models and development patterns in Latin America | Assessment of the economic impact of Huanglongbing disease on Mexico's citrus chain | Climate change and food security: cross-cutting axes of agricultural policies | Agro-biotechnologies: bio-logical tools at the service of agriculture | Project "The new face of rural poverty in Brazil: transformations, profile and public policy challenges"

IICA

New realities, new paradigms: the new agricultural revolution

ARTURO BARRERA[1]

Summary

World agriculture is undergoing a transition to a new technological paradigm very different from that of the green revolution. The development of this new paradigm is being driven by the ongoing "bio", "info" and "nano" revolutions, and the new demands of society and the markets. The agricultural revolution of the 21st century is deeper and more far-reaching than previous ones: it is an organizational revolution of knowledge management and of convergences between technologies. One of the effects of this new agricultural revolution is a notable increase in the sector's potential to create wealth. This article is intended to contribute to the characterization of the new paradigm of agricultural technological development and the type of agriculture that is taking shape.

[1] *Manager of IICA's Innovation for Productivity and Competitiveness Program, arturo.barrera@iica.int*

KEY WORDS: AGRICULTURAL DEVELOPMENT, BIOTECHNOLOGY, MODERNIZATION, TECHNOLOGICAL CHANGE, INNOVATION, NANOTECHNOLOGY, INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTS)

Introduction

We are witnessing the emergence of "post-green revolution agriculture." The paradigm of the green revolution has run its course and has been obsolete for some time, its effectiveness called into question by climate change and the new techno-economic and organizational paradigm based on the advances in information and communication technologies (ICTs) and modern biotechnology.

The green revolution led to a particular way of conceiving and "doing" agriculture, understanding agricultural modernization and measuring sectoral performance, accompanied by a specific sectoral institutional framework.

While this development signals the end of an era and its paradigm, the term "post-green revolution agriculture" is insufficient to describe or characterize the new era that is beginning to unfold. For the purposes of this article, a paradigm is a set of values, concepts and definitions that makes it possible to address a problem or issue and shapes specific ways of understanding the world and intervening in it. More specifically, a technological paradigm is the "creation of innovation opportunities measurable by changes in the basic technical characteristics of the "artifact(s)" concerned" (ECLAC 2008:149)[2]. From a broader perspective, a paradigm has to do with the way we conceive and "do" agriculture, promote agricultural modernization and measure sectoral performance.

The paradigm of the green revolution

The technological paradigm of the green revolution was the product of the industrial society and "food Fordism." The revolution was linked to a specific way of understanding modernity and promoting modernization, since it developed in an intellectual climate in which a model of modernity was held up as the ideal and a single path was proposed for achieving it. The green revolution occurred at a time when humankind was creating new risks, but was not aware of them and so failed to address them.

This paradigm led to a particular way of conceiving and "doing" agriculture, understanding agricultural modernization and measuring sectoral performance, accompanied by a specific sectoral institutional framework. The key technological challenge of the green revolution was to increase yields per hectare (mainly yields of wheat, rice and corn) in order to combat hunger, especially in the Asian countries.

Although the increases in production achieved in the 1960s, 1970s and 1980s were mainly due to higher yields, the agricultural frontier and water were not limiting factors, as the growth of production in Latin America in those decades demonstrates. The negative environmental externalities generated by the intensive use of fertilizers and agro-chemicals to control pests and diseases were not constraints either.

The technological challenge was met by an institutional framework based on public research, with the Consultative Group on International Agricultural Research (CGIAR) facilitating a great deal of technology and germplasm transfer worldwide. As FAO (2004:32) has observed, "the international flow of germplasm has had a large impact on the speed and the cost of crop development programmes of national agricultural research systems."

The green revolution led to the development of a form of agriculture heavily dependent on technological advances such as high-yielding varieties, obtained through conventional genetic improvement, the intensive use of technological inputs like fertilizers and agro-chemicals that made it possible to tap the genetic potential of new varieties, and greater utilization of the modern

[2] In the case of the digital paradigm, for example, the "artifacts" include semi-conductors, microprocessors and data storage systems. In the case of the biotechnological paradigm, they are the analysis and modification of genetic material, high-speed sequencers, molecular markers, genes and DNA (ECLAC 2008).

A number of models and trajectories to modernity are on offer and we no longer have absolute faith in science and technology's capacity to control the world and make it more predictable. It is also a time of systemic risks.

economic rationality of cost-benefit analysis through the increased use of management technologies. The green revolution championed these concepts as the keys to agricultural modernization.

The green revolution's impact on higher yields and production was evident, as was its contribution to reducing world hunger, mainly in Asia. According to FAO, between 1963 and 1983 total production of rice, wheat and corn in the developing countries increased by 3.1%, 5.1% and 3.8% per year, respectively. Over the next decade, the annual increases in the production of the same crops were 1.8%, 2.5% and 3.4%, respectively (FAO 1996).

The environmental and social debates on the costs of the revolution were intense, especially in the 1980s and 1990s. Different authors point to environmental degradation, genetic erosion, the exclusion of women and increased inequality as some of the costs. The most obvious cost – on which there is consensus – was the damage done to the environment.

During the 1990s, basically as a result of the 1992 United Nations Conference on Environment and Development, the idea of a "new green revolution" or a "second green revolution" was put forward, based on the principles of sustainable development. One example of this attempt to reduce the environmental costs of the green revolution was the development of the concept of integrated crop management, which is achieved through the integrated management of pests and soil nutrients.

It soon became clear, however, that these solutions – based, as they were, on the paradigm of the green revolution – were insufficient and that the new digital and biotechnological revolutions and the emergence of the issue of intellectual property for plant genetic materials were beginning to effect far-reaching changes that would have a major impact on the technological paradigms of different production activities.

It is worth remembering that the 1990s saw the first commercial releases of transgenic crops, the emergence of functional foods, the first report of the Intergovernmental Panel on Climate Change and the development of the concept of the risk society. The same decade also witnessed the emergence of the concepts of expanded agriculture, knowledge management and knowledge and learning-based economies. It was a time when new questions were asked: what is agriculture and how can agricultural technological development be achieved? At the sectoral level, it marked the start of the transition to a new technological paradigm.

The new paradigm: an info-biotechnological agricultural revolution[3]

Today we are witnessing a transition toward the consolidation of

The new technological revolutions underway – digital and biotechnological – as well as the emergence of the topic of intellectual property for phytogenetic materials, were beginning to cause major and far-reaching transformations that would significantly impact the technological paradigms of the different productive activities.

[3] *In the case of the digital paradigm, for example, the "artifacts" include semi-conductors, microprocessors and data storage systems. In the case of the biotechnological paradigm, they are the analysis and modification of genetic material, high-speed sequencers, molecular markers, genes and DNA (ECLAC 2008).*

The new paradigm is substantially altering some of the basic characteristics of the green revolution. Some cases in point are:

a. The uniform farm management model, which is increasingly being replaced by precision agriculture.

b. The high use of chemical inputs, challenged because of its effects on the concentration of greenhouse gases.

c. The focus on a single type of agriculture, which is being replaced by a variety of ways of "doing" agriculture: traditional, transgenic, organic, etc.

a new agricultural technological paradigm. Since this post-green revolution technological paradigm is developing in the context of late modernity, it is drawing on the knowledge accumulated in recent decades and beginning to address the risks created during the same period and the new demands of society and consumers with regard to environmental issues. A number of models and trajectories to modernity are on offer and we no longer have absolute faith in science and technology's capacity to control the world and make it more predictable. It is also a time of systemic risks.

This new paradigm is developing at a time when science and technology are beginning to seek new areas of convergence, and systemic approaches are gaining ground. The new agricultural technological paradigm is part of this new global intellectual and technological climate.

The new agricultural technological paradigm is framed within the techno-economic paradigm created by the large-scale utilization of ICTs and biotechnology. It is also framed within the new demands of society, the markets and agrifood chains, including the differentiation of products, quality and safety, biosafety, animal well-being and the sustainable use of biodiversity and natural resources.

As ECLAC (2008:149) has stated, the generation of techno-economic paradigms is based on innovations that are capable of redefining "the trajectory not only of the technological and economic spheres but also of the social sphere." Furthermore, this new paradigm is developing at a time when science and technology are beginning to seek new areas of convergence, and systemic approaches are gaining ground. The new agricultural technological paradigm is part of this new global intellectual and technological climate.

The key agricultural technological challenge of the 21st century is to produce more, better and more diverse food and non-food agricultural products by means of productive processes that:

- Generate smaller amounts of greenhouse gases
- Make more efficient use of water
- Use basically the same amount of land
- Respond to new biotic and abiotic stresses caused by climate change
- Permit greater monitoring by society of the technologies used.

All these are new production constraints and requirements that were practically non-existent at the time of the green revolution (Table 1).

Table 1. Change in the paradigm of agricultural technological development.

Aspect	Green revolution	New agricultural revolution
Core concept	**Research**	**Innovation**
Main objective of research/innovation	Higher yields and greater resistance to pests and diseases.	Higher yields, more stable production systems, improvement of product quality and sustainable use of natural resources.
Approach	Focus on supply and primary production. Research prioritizes only some crops.	Focus on the demand from businesses and innovations throughout the chain. Innovation incorporates a wide range of products.
Principal technology	Conventional genetic improvement.	Biotechnology, ICTs and nanotechnology.
Type of inputs	Increasingly chemical.	Increasingly biological. Importance of biodiversity.
Main protagonists of research – innovation	Public institutions.	Private enterprises and public institutions.
Goods produced by research/ innovation	Public goods.	Increasingly, private goods and club goods.
Intellectual property	Not important.	Increasingly a key factor.
Type of knowledge that is important	Explicit.	Explicit and tacit. Growing importance of knowledge management.
Characteristics of agricultural modernization	Increased use of the cost-benefit approach and chemical inputs.	Various trajectories and models. Continuous improvement and good agricultural practices.
Performance measurement	Yield per hectare.	Multiple. Yield per unit of water, active/hectare component, carbon and water footprint.
Institutional framework	National agricultural research systems.	National agrifood innovation systems.

In this context, the objectives of "sectoral" technological development are to increase productivity, improve the industrial, nutritional and organoleptic quality of products and ensure the sustainable use of natural resources. Another goal is "the stability and resilience of production systems" (World Bank 2008).

As a result, there is no single option and trajectory for agricultural modernization. Modernization no longer means the use of specific inputs and a single approach.

The key aspect of the agricultural technological challenge of the 21st century is fully consistent with the new technological paradigm of ICTs and biotechnology, whose core objective is to use less raw materials and energy through the intensive use of information, knowledge, services and gray matter (Pérez 1998).

From this perspective, bio-technology and its application to agriculture and the food industry is a good example of a technology that makes intensive use of processing and information (in this case, genetic information) and saves energy when used in agro-industrial bioprocessing. Similarly, the utilization of ICTs in precision agriculture is a demonstration of the intensified use of on-farm (and off-farm) information and how it improves the way in which the different factors of production are used, including water, fertilizers and pesticides. Moreover, since one of the potential uses of nanotechnology is precision agriculture, its contributions will strengthen the benefits and chief characteristics of this type of agriculture.

If biotechnology, ICTs and nanotechnology have increasingly broad and unanticipated applications in the technological development of agriculture, the convergences between them will simply multiply those applications. One only has to look at what is happening with bioinformatics and the incipient uses of nanotechnology in the development of precision agriculture. Other technological convergences are bound to emerge, since we are only just beginning to see the development of this trend[4].

In the era of knowledge-based agriculture and the new food revolution, the method used to measure sectoral performance is beginning to incorporate new indicators such as the yield by unit of water and the carbon footprint (Barrera 2010). Another performance indicator that is likely to be used increasingly is that of active components of agricultural products by unit of land or water. "Site-specific" and "precision" technologies are beginning to play a key role, as are differentiation and quality management and assurance (see Text Box 1).

A key aspect of the change in the technological paradigm of agriculture has to do with the predominant concepts that have sustained agricultural technological development and are responsible for the chief characteristics of the national institutional frameworks that promote it: the concepts of research and innovation and the national systems devoted to these areas.

[4] The European Commission (2004) believes that the next big wave of innovations will come from the convergence of four technologies: nanotechnology, biotechnology, information and the advances in neuroscience. The first three clearly relate to the agricultural area, the fourth less so, but it is important to bear in mind that the research centers and global food companies are investing more resources in efforts to gain a better understanding of the relationship between the brain and nourishment.

The way in which the institutional framework took up the gauntlet and addressed the technological challenges of the green revolution already mentioned was very different from the approach adopted for the new agricultural revolution. In the first case, the task fell to the national agricultural research systems; today it is the responsibility of the national agrifood innovation systems.

There are major differences between the institutional arrangements in each case, including the following:

a. The national agricultural research systems were simple and linear, with a small number of protagonists; the current national agricultural innovation systems, on the other hand, are interactive and complex, with a multiplicity of stakeholders and subsystems.

b. In the past, research was the only source of innovation; in today's systems, that is no longer the case.

c. The systems of the green revolution were focused on the supply of research. Today, the innovation systems respond increasingly to the demand from businesses, where the application of knowledge is fundamental.

d. In the national research systems, the emphasis was on explicit knowledge; in the national innovation systems, tacit and explicit knowledge are equally important.

e. Today, the governance of the system is becoming an important issue, which was not the case with the research systems.

Another important aspect of the institutional framework (understood in a broad sense) has to do with the types of goods generated by research and innovation processes. In the paradigm of the green revolution, agricultural research mostly generated public goods. In the present technological and institutional paradigm, on the other hand, national innovation systems increasingly generate private and club goods. As a result, intellectual property management has become a crucial issue.

> The new revolution may be bio-technological, but it is not only bio-technological; it is digital, but not only digital; it is nanotechnological, but not only nanotechnological. This revolution is more than bio-technological, more than digital and more than nano-technological. It is a revolution of knowledge management and technological convergences.

At the heart of the new agricultural technological paradigm, in addition to the current technological revolutions and the new demands of society and the markets, is a new way of "doing" science and technology. As Trigo (2010) points out, the production function used to "produce" knowledge and technology has changed. Biotechnology and ICTs have played an important role in those changes. In fact, biotechnology and ICTs have changed not only the production function of agricultural and food activities, but also the one used to generate science, technology and innovation. Furthermore, due to the complexity of 21st century societies and the problems that have to be addressed, the scientific and technological approaches are more systemic and multidisciplinary. ICTs have transformed the ways of accessing and managing the research centers' data and information. Internet and its logic of networks has fostered and multiplied collaboration on a global scale. All this has had an impact on productivity and the costs of generating new knowledge.

The agriculture of the 21st century

Based on the new technological paradigm described above, the agriculture of the 21st century is beginning to experience a new revolution.

The new info-biotechnological agricultural revolution is a direct consequence of the information society and the knowledge economy. It marks a reconceptualization and reinvention of what humankind understands by agriculture and how it is carried out. The revolution is generating new potential to create wealth and new opportunities for innovation. Like all technological revolutions, it is generating new products, such as transgenic crops, functional ingredients and high-value inputs for different industries.

The new revolution may be bio-technological, but it is not only bio-technological; it is digital, but not only digital; it is nano-technological, but not only nano-technological. This revolution is more than bio-technological, more than digital and more than nano-technological. It is a revolution of knowledge management and technological convergences. The agriculture that is taking shape as a result of this new revolution is more about networks and interactivity, DNA and software, site-specific and precision technologies, and terroirs and clusters (Table 2).

We are on the cusp of a new era whose changes are affecting the most diverse areas of human activity, including agriculture and food production. The principal technological dynamics of agriculture come from the dynamics of cross-cutting technological revolutions, such as ICTs and the biotechnology, and not the largely internal technological dynamics of agriculture, as occurred with the green revolution. The same is beginning to happen with nano-technology.

The agriculture of the 21st century is also based on new types of businesses and work, mainly in a more empathic relationship with natural resources and nature. Agriculture is increasingly viewed as a pillar of the bio-economy and a key activity for tackling climate change.

Table 2. Changes in the conceptual framework and way of "doing" agriculture.

Aspect	Green revolution	New agricultural revolution
Definition as an economic activity	Primary activity	Expanded agriculture, agrifood chains
Principal objective of agriculture	To supply food	To supply food and functional ingredients, produce environmental services and generate non-food agricultural products
Type of business	Fordist – Taylorist	Responsible, adaptive and flexible
Obsession of the chain	Quantity and yield	Quality, innovation and reputation
Type of products	Commodities	Increasingly differentiated
Principal characteristic of the work	Manual and repetitive	Increasingly sophisticated and creative
Relationship with nature	Indolent	Empathic and responsible
Carbon content	High in carbon	Low in carbon
Management logic of agriculture	Uniform	Use of site-specific and precision technologies
Type of agriculture	Homogeneous	Varied. More about networks and interconnections. More about terroirs
Type of economy	Industrial economy	Knowledge economy. Bio-economics

Final considerations

The green revolution was one of the major revolutions of the 20th century and one of humankind's success stories.

We are embarking upon a new agricultural revolution that is deeper than the green revolution and whose consequences will be more far-reaching. This is due to the scope of the digital, biotechnology and nano-technology revolutions and the convergences between them. The ways in which these technologies are applied in the agricultural and food sector will undoubtedly continue to surprise us in the coming decades.

The green revolution was a major process of "artificializing" agricultural production, reflected basically in a sharp increase in the use of, and dependence on, chemical inputs. The new agricultural revolution is, in some sense, a process of "naturalizing" production, reflected in the growing use of biological inputs, although it does include aspects of "artificialization" – genetic engineering, for example.

Every era and society has its own fears and bogeymen to deal with, and each of the revolutions analyzed in this article came about in response to a global concern. In the case of the green revolution, it was the Malthusian fear of hunger. In the case of the new agricultural revolution, it is the fear of global warming, that Gaia will pass the point of no return.

The green revolution was a great advance for humankind, especially for the developing countries. Similarly, the new technological and agricultural development paradigms of the 21st century allow us to feel moderately optimistic that we will be able to produce sufficient good-quality food to feed the planet's nine billion inhabitants in 2050. However, this will undoubtedly depend on how different countries and social groups access food, which has to do with how globalization is organized.

Text Box 1. Precision technologies: one of the most notable features of the new agricultural revolution.

One of the principal features of post-green revolution agriculture is the site-specific management techniques that are beginning to be used for different production resources and the greater precision employed in agrifood research processes.

Precision agriculture is gaining ground the world over. This growth is being driven by the increased, intensified use of the many more sophisticated tools provided by information and communication technologies. Increasingly, the applications and potential of this type of agriculture are being reinforced by the advances of another technological revolution: nano-technology.

Precision technologies are also making their presence felt in other areas besides what is now referred to as "precision agriculture." Biotechnology, for example, is making it possible to extend the logic and dynamics of precision to the other end of food chains, to consumption by individuals who are increasingly demanding and obsessed with their health. Thanks to the progress being made in the area of nutrigenomics, in the near future it will be possible to tailor the dietary intake of individuals to their nutritional needs.

Biotechnology has also fostered precision practices in an area that is important for agriculture – genetic improvement. The genetic improvement of trees, crops and animals is now more "precise" and rapid because it is "targeted," based on high-speed sequencers and molecular markers.

However, nanotechnology is the technology that will expand and deepen the logic of precision in the future. And it will do so in the different links and areas of food chains. For example: a) it will strengthen precision agriculture; b) it will make it possible to create intelligent food, with nutrients located in nano-capsules that the organisms of humans and animals will utilize better; c) it will permit better safety management through the use of interactive containers and in other ways; and, d) it will strengthen the prevention and control of plant and animal diseases.

In short, precision technologies are one of the main features of the new agricultural and food revolution, and their impact will become even more pronounced in the years ahead.

References:

Barrera, A. 2010. El Contexto Mundial de la Nueva Revolución Alimentaria. In "La Agricultura Chilena en la Nueva Revolución Alimentaria." Santiago, CL, Editorial Universitaria.

Barrera, A. 2010. ¿Qué es lo más característico de la Nueva Revolución Alimentaria? Available at www.arturobarrera.com

ECLAC (Economic Commission for Latin America and the Caribbean). 2008. Structural change and productivity growth 20 years later. Old problems, new opportunities. Santiago, CL.

European Commission. 2004. Converging Technologies: Shaping the Future of European Societies. Brussels.

FAO (United Nations Food and Agriculture Organization). 1996. Lessons from the green revolution: towards a new green revolution. Rome, IT. Technical background documents, World Food Summit.

________. 2004. The State of Food and Agriculture. Agricultural Biotechnology: meeting the needs of the poor? Rome, IT.

Pérez, C. 1998. Desafíos sociales y políticos del cambio de paradigma tecnológico. Presentation made at the seminar: Venezuela, Desafíos y Propuestas. Caracas, VE.

Tiju, J; Morrison, M. 2006. Nanotechnology in Agriculture and Food. Institute of Nanotechnology. European Nanotechnology Gateway.

Trigo, EJ. 2009. El marco institucional para la innovación tecnológica en la agricultura y la alimentación. In "La Institucionalidad Agropecuaria en América Latina: Estado Actual y desafíos. Roma, IT, FAO.

World Bank. 2008. Agriculture for Development. Washington D.C.