Information and communication technologies for agricultural development in Latin America

Trends, barriers and policies

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The preparation of this document was coordinated by Mônica Rodrigues and Adrián Rodríguez, staff members of the Agricultural Development Unit, of the Division of Production, Productivity and Management of the Economic Commission for Latin America and the Caribbean (ECLAC), in the framework of the project “Inclusive political dialogue and Exchange of experiences”, under the Alliance for the Information Society programme phase 2 (@LIS2), which is jointly financed by ECLAC and the European Union and implemented by the Division of Production, Productivity and Management .

The coordinators would like to thank Javier Meneses, Francisca Lira and Eric Anderson, ECLAC consultants, for their support in preparing and editing this publication. They also would like to thank Octavio Sotomayor of the Agricultural Development Unit, for his valuable comments and contributions.

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The electronic version of this document is available at: http://www.eclac.org/SocInfo.

LC/R.2187 • February 2013 • 2013-50

Contents

Introduction

Information and communication technologies (ICTs) can make a powerful contribution to agricultural development. Not only can ICTs be applied in virtually every sphere of agricultural production and farm management; they also have the capacity to transform production and marketing and, even more importantly, the flow of information and knowledge within the sector.

Farmers of course need physical inputs at every stage in the value chain, but they also need information, which can be more readily or efficiently obtained through ICTs. This means that the transforming potential of ICTs reaches the different segments and activities of the agriculture sector. Introduction of ICTs in business administration and finance, for example, can lead to greater efficiency, lower costs, and sounder decision-making. Digital production technologies, in turn, can make for more rational use of resources, higher profit margins, and greater productivity. The use of digital tools and instruments can also enhance the sustainability of agriculture through more rational use of chemical inputs and the consequent reduction in environmental residues, and through the prompt and integrated treatment of plant and animal diseases.

Although many studies recognize the potential of ICTs for boosting efficiency in productive processes and in natural resource management –and although some of those studies have succeeded in measuring such impacts– there is still a lack of sound evidence about the presumed benefits of introducing ICTs in the agriculture sector. Despite the growing number of projects and policies in this area under the most widely varying conditions of economic development, they are rarely subjected to consistent and systematic impact assessments, a situation that undermines the very continuity of these initiatives.

The present publication has been prepared in this dual context of abundance (of ideas, opinions and initiatives) and scarcity (of systematic and organized information) on the potential of ICTs to promote socially inclusive and environmentally sustainable agricultural development. In Latin America, social inclusion and environmental sustainability in agriculture are especially relevant issues, in light of the great structural heterogeneity within the sector and, more recently, the stepped-up pressures on natural resources resulting from the boom in international commodity markets. Yet, the adoption of ICTs in agriculture cannot be expected by itself to reduce production asymmetries and enhance social inclusion. On the contrary, the dissemination of ICTs could indeed produce new gaps by replicating the sector's historic disparities.

Taking advantage of ICTs for reversing patterns of unequal development and promoting environmental sustainability in the region's agriculture will require policies for overcoming barriers to their adoption in those segments that are lagging furthest behind. One way to pursue this goal is to identify successful policies and projects in neighboring countries and in other continents with similar patterns of economic and social diversity and adapt them to countries of the region. This publication is intended to contribute to the identification of successful experiments in fostering the use of ICTs in agriculture. "Success" is defined in terms of the possibilities for broad adoption by farmers, replicability, sustainability over time, and the potential to have a positive impact on economic and social inclusion or on the sector's environmental footprint, or on both.

A. Definitions and the theoretical and methodological focus

It is useful to begin by presenting the ICTs that have been considered in this publication. The main selection criteria were, on one hand, the prospects of use of these technologies in the agriculture sector and, on the other hand, the potential for generating greater value and making the activity more sustainable. ICTs include a variety of manufacturing industries (electronic components, computers and peripherals, telecommunications equipment, multimedia equipment, measurement instruments and electronic consumer goods such as television sets and radios) and of services (telecommunications, computing, software, maintenance, data processing and storage, webpage design, among many others) that develop generic or specific applications for different economic sectors.

In the case of agriculture, the most widely used ICTs are those that allow basic communication: radio, television and, now, cell phones (use of which has exploded in recent years). But there are also important areas of ICT application in production and marketing: this is particularly the case for technologies associated with precision agriculture, information and traceability systems. Given the importance of these technologies and their recent applications in agriculture, several chapters of this publication will look at them from a variety of perspectives. Many other agricultural uses of ICTs –for example, in early warning systems, remote diagnosis of pests and diseases, virtual communities, mobile banking, electronic commerce and e-government– are also examined in the course of the publication.

The theoretical and methodological approach adopted in the various chapters (which are mutually complementary) analyses technological development with a central focus on the dynamic evolution of economic systems. According to this approach, which is useful in various lines of economic theory, knowledge and innovation are generated through competitive and collaborative interactions among agents, markets and institutions. Such interactions can therefore speed the development of economic systems. Given their crosscutting nature and their impact on communications and data management, ICTs have a direct effect not only on interactions between agents and their environment, but also on the forms of production, marketing and learning within production chains and, more broadly, within societies. These technologies, then, have the capacity to transform directly the manner in which economic systems evolve.

With this theoretical framework, the studies seek to analyze some of the questions that arise with respect to the multiple dimensions of agricultural development that are affected by the new ICT paradigm. For example, **Rodrigues** argues that the development of ICT-based technologies in agriculture is a result of the simultaneous evolution of multiple technological systems exchanging information and knowledge within a common institutional and regulatory framework. **Rama and Wilkinson** analyze recent trends in ICT access and use in rural areas of Latin America in light of the spatial transformations that have also been promoted by the digital revolution. **Hopkins et al.** provide a detailed description of ICT applications in agriculture, based on progress on the supply side, i.e., in the development of generic ICTs and their adaptation to agricultural tasks. **Gutman and Robert**'s and **Nagel**'s chapters, in turn, stress the role of ICTs in transforming the interactions and learning processes of, respectively, commercial and small farmers inserted in the agricultural value chains, thereby speeding their development.

In contrast to conventional theories of technological dissemination, which emphasize the relative abundance of productive resources for explaining why one technology or another (capital-intensive or labor-intensive, for example) is adopted, the systemic approach adopted in this publication seems better suited for analyzing the variety of situations and technological levels to be found in the Latin American agriculture sector. Here, that diversity is explained by specific local and historical conditions, by the characteristics of the interrelationships between stakeholders, and by the scope and effectiveness of policies to foster systemic and sectoral technological development. The key challenge in this context is to present and analyze the information concerning these factors in an organized and systematic way, while drawing more generic inferences from case studies and specific experience. One of the central objectives of this publication, then, is to identify common patterns of agricultural development based on ICTs.

Given the complexity of the topic and the lack of empirical research for corroborating and measuring the potential impact of ICTs on information flows and the generation of knowledge and innovation in agriculture, the various studies that make up this publication have drawn upon three basic data sources: (i) available statistics on ICT access and use in rural areas and in agriculture; (ii) ICT impact studies, even those that do not refer specifically to Latin America or to agriculture; and (iii) the opinions of experts consulted in the course of interviews and surveys.

The different chapters have made progress in handling the issue of ICTs for agricultural development in Latin America. First, the studies presented here have advanced in systematizing the information available in academic studies, working papers of local and international institutions, projects and assessments conducted by governments and NGOs, and official national statistics from Latin America and other regions. Second, using the information collected and applying the common theoretical framework, efforts have been made to draw inferences about the main tendencies in the use of ICTs in agriculture and their impact on the sector's development path. Third, an inventory of successful experiments and policy recommendations has been compiled and classified according to their expected impact or, alternatively, according to the conditions for feasibility of such initiatives, which can be of great use in preparing projects to encourage the use of ICTs in Latin American agriculture.

B. Trends in the use of ICTs and their impact

One of the principal outcomes of the studies presented here has been to corroborate, through a great variety of case studies, the notion that agriculture has been decisively transformed by the adoption of ICT applications. Yet, this has not in itself been sufficient to eliminate or even reduce the asymmetries persisting within the sector.

Rama and Wilkinson *a*rgue that the rapid spread of cell phone use in rural areas of Latin America is allowing regional agriculture to skip over some steps in terms of technological development, particularly with the advent of 3G and 4G technologies. Despite these trends, the authors conclude that farmers' access to ICTs is still constrained by distance to population centers and other factors such as income, education level, and the integration of producers into networks and value chains. These findings are also validated by **Nagel**, who refers specifically to the constraints facing small farmers in accessing and making productive use of ICTs.

Gutman and Robert conclude that the separation between the place where agricultural production takes place (the farm) and the place where knowledge applied to the sector is generated (increasingly in the input production and marketing segments) has accelerated technological dissemination in the agriculture sector through so-called "technological packages" which include machinery, software and various inputs. This dissemination is based on the formation of stakeholder networks, in which technical advisors (private consultants, employees of input or marketing firms, university extension services and government institutions, etc.) play a special role in catalyzing technological diffusion in the agriculture sector. The adoption and success rates of new technologies in agriculture still depend, however, on the development of internal capacities that allow producers, on one hand, to select, implement and make correct use of such technologies and, on the other hand, to interact and learn with them. Without the development of these internal capacities, the impact of ICT-based technologies on learning and knowledge generation in agriculture is reduced.

Hopkins et al. indicate that the use of ICTs has reduced the risk of losses in agriculture thanks to the possibility of real-time communication and response and the dissemination of best practices, which also tend to be more environmentally friendly, acting in the long-term as a strategy for mitigating risks, particularly climatic ones. As well, ICTs encourage more efficient monitoring of agricultural tasks, making it possible to manage geographically scattered areas jointly and allowing farmers to establish immediate contact with workers, other producers, and other players in the agricultural value chain. Although the cost of mobile technologies (including cell phones) is clearly declining, other challenges to the efficient use of ICTs in agriculture are growing, in particular the need to coordinate and pool the efforts of increasingly complex networks of stakeholders and technologies.

Along with these discoveries, a set of technological areas or niches has been identified in which the specific features of agricultural activity have shaped peculiar tendencies among ICT producing sectors. Such niches have been found, especially, in countries and localities where agriculture is very dynamic and well linked to sophisticated international and domestic markets. Moreover, the cases examined reveal interactions and complementarities among a great variety of stakeholders and institutions capable of generating demand for ICT applications in agriculture and at the same time supporting the development of solutions on the ICT supply side.

Rodrigues presents some case studies as the basis for discussing the evolution of ICTs in agriculture. The cases examined, drawn from Brazil and Argentina, show how the emergence of ICTs in agriculture is shaping not only productive practices but also the regulatory framework for food production and marketing. At the same time, there are impacts in the opposite direction, i.e. from agriculture toward ICT producers. In effect, Rodrigues shows that the development, location and structure of agricultural software industries in Brazil and of precision agriculture in Argentina are conditioned by the evolution of agricultural technology systems in those countries. Of particular interest are the variables related to the dynamism of agriculture and the existence of stakeholders who can support the development of ICTs with specific knowledge of the needs and characteristics of the agriculture sector, such as universities specialized in agrosciences and firms that manufacture or distribute machinery and other agricultural inputs.

C. Case studies

The case studies presented in the different chapters, in some cases refering to the same technology, have distinct analytical purposes, consistent with the thematic objectives of each chapter. In this respect, the chapters are to a large extent complementary and can be taken as illustrating the different topics and approaches associated with ICTs applied to agriculture. For example, the sections on precision agriculture in the various chapters offer different information on the applications and impacts of that technology and at the same time allow for comparison of different analytical approaches.

The case studies included in each chapter are intended to do more than simply illustrate the theoretical arguments contained in this publication: the idea in fact is to generate an inventory of experiments that might be of real use in the design and implementation of policies to foster ICT use in agricultural development. Thus, in those cases identified as successful or as holding lessons that can be transferred to other countries, the authors have attempted to follow a common analytical structure that can readily systematize the experiments described in this publication. That structure includes: (i) a general description of the technology; (ii) an assessment of its use in Latin America; (iii) summaries of different experiences within and beyond the region to illustrate the potential of the technology for accelerating agricultural development; and (iv) a discussion of the opportunities and limitations facing countries of the region in making use of the technology.

As stated earlier, case studies involving precision agriculture (PA) and traceability systems have been included in several chapters, in recognition of the intensive use they make of ICTs and their potential impact in the agriculture sector.

PA refers to management of the temporal and spatial variability inherent to agriculture, with a view to reducing costs, increasing economic benefits, and minimizing environmental impacts. PA can be highly intensive in its use of ICTs at all stages: data collection, processing and interpretation, and variable application of inputs. Although the idea of adjusting inputs to the variability of field conditions within the farm began in the ´80s, adoption only really got underway in the last decade with the employment of satellite-based GPS and GIS and automated sensor-controlled application equipment. Traceability, on the other hand, can be understood as the possibility of tracking or certifying the origin of products (foodstuffs and others) through the different stages of the production, processing and marketing chain, and it too is highly intensive in the use of information.

Therefore, PA is eminently supply driven and promoted particularly by the agricultural machinery sector. It corresponds also to efficiency concerns, which are likely to increase as the management of inputs becomes more decisive to competitiveness. While the importance of precision farming is correlated with the variability of agricultural conditions, it also makes it possible to combine scale with the intimate knowledge of the land which has traditionally been a competitive advantage of the small farmer. Traceability, on the other hand, is predominantly demand driven, although it can also be a key tool for farm-level strategies of product differentiation. Health safety concerns, particularly as defined in European Commission directives, are increasingly imposing the adoption of traceability systems as the condition of entry to international markets. Transnational retail, which also adopts different traceability procedures as the basis for access to key domestic and export markets, is ensuring that these ICT technologies are more widely integrated into agriculture as standard practices.

Beyond PA and traceability, many other ICT-based agricultural technologies are analyzed in one or more chapters of this publication. The chapter by **Hopkins et al.**, in particular, details and systematizes the innumerable areas in which ICT can be used in agriculture. According to them, tendencies in the use and dissemination of ICT in Latin American agriculture are extremely uneven among countries, localities and types of producers. This heterogeneity opens the possibility for transferring technology from the more advanced countries and localities to the less developed ones, which in some cases might be able to "skip over" stages in the process of introducing and disseminating ICT in agriculture.

Having a clear picture of the different situations in Latin American agriculture and the fundamental features of each technology applied to the sector is extremely important for the successful transfer and adaptation of experience among countries. For example, PA has its greatest potential in extensive and mechanized farming, and although its high cost and the demands it imposes in terms of machinery and user skills generally render it unviable in small-scale agriculture, its essentials – which involve recognizing and capitalizing on the natural variability of agriculture – can be applied in different situations.

Hopkins et al., and **Gutman and Robert** highlight the role of collective and cooperative activities for making viable the use of certain ICT-based technologies in agriculture, including PA and other technologies for managing risk, such as the precision irrigation and integrated pest and disease control. Such arrangements allow producers to share not only the cost of equipment but also the knowledge needed to operate the machinery and interpret the results. In this respect use of the Internet, and of virtual communities in particular, can be very useful, as demonstrated in some of the experiments analyzed.

D. Policy recommendations

For agricultural businesses to adopt ICTs is a complex process, subject to a series of external pressures flowing from the requirements of market competitiveness, social demands and communication needs generated in farm families themselves, the supply of consumer goods and demonstration effects from other social and productive sectors. Public and private institutions also influence the adoption of ICTs to the extent that they control the availability of electronic transactions and processes and, in the case of governments, through their digital development activities and policies. The effectiveness of policies can in fact make a real difference in the level of adoption, and even more in the observed impacts of ICTs on economic activities and on societies. That is why, although in general terms there is a correlation between levels of economic development and digital development, at comparable levels of per capita income some countries have achieved greater digital development.

Policies and institutions are central to determining the impact that the new technologies will have on economic systems, to the extent that they serve as facilitators, at the macro level, of firms' strategies for adopting and using the technologies. In this publication, the issue of policies for promoting the use of ICTs for agricultural development is approached from two different perspectives. First, some chapters offer suggestions for policies to address the limitations identified in each specific thematic area; the chapter by **Nagel**, for example, offers a broad inventory of policies for overcoming barriers to the adoption of ICTs among small farmers. Second, the chapter by **Chavarría** addresses the issue of ICTs for modernizing public agriculture institutions, which in the end will have an impact on the way governments implement agricultural policies and on their results.

According to **Nagel**, the level of farmers' access to ICTs is the lowest of all occupational categories, including those engaged in rural non-agricultural activities (RNAA). However, he identifies situations in which groups of small farmers are using ICTs to a particularly high degree, either because they are integrated into markets, participating in support programmes, or living in areas targeted by development policies.

As **Nagel** sees it, there may be limitations on the expansion of ICT use among farmers both on the technology supply side (availability and quality of connections, equipment prices, relevance of contents for agricultural activity, etc.) and on the demand side (educational level and age of users, traditional cultural patterns, undemanding markets, etc.). Both sets of constraints can be dealt with through public policies, although some will require longer-term efforts. Educational barriers, in particular, should be treated as a parameter in the planning of short and medium term strategies for digital expansion, with a view to offsetting cognitive deficits through training, information and motivation activities.

On the technology supply side, a key challenge for the region is making broadband universally available. There are significant differences among countries in the quality of broadband services: the speeds normally available in rural areas are inadequate for anything more than basic communication. The rapid spread of cell phones in rural areas offers an interesting platform for introducing ICTs in agriculture, yet at the present time supply and price constraints make it premature to assert that rural populations and farmers can be recruited en masse to this solution. For now, shared access centers (telecentres, commercial cybercafés and, in some cases, rural schools) constitute an important mechanism for making ICTs available to the more isolated communities. Public policies should consider these as advanced platforms for implementing a comprehensive strategy of agricultural and rural development that includes training, provision of information, extension services, productive development and public or community-sponsored digital services.

Policies must include general measures to improve ICT access in rural areas, along with specific strategies to foster their use and adoption by farmers. This implies strategies for providing infrastructure, establishing access points, digital training and contents production, along with incentives to integrate ICTs into the technological systems of firms, agrifood chains, extension services etc. The heterogeneity of the farming population also requires differentiated strategies for fostering ICTs to avoid widening the domestic digital divide.

Agriculture is not a priority sector in national strategies for digital development, nor do agriculture ministries (with a few exceptions) pay much attention to digital issues in their sector policies. These are the conclusions reached by **Nagel** and **Chavarría** in their analyses of digital agendas and sector policies of Latin American countries. These authors, recognizing that some measures exceed the bounds of the agriculture sector, call for articulation between sector institutions and national digital development agencies. If the intention is to boost ICT access, use and impact in agriculture and in public institutions supporting the sector, they argue, agriculture will have then to be raised to priority status on national digital agendas. But the existence of national agendas is not enough in itself: there must also be specific strategies for agriculture.

According to **Chavarría**'s analysis, the public institutions that provide services to agriculture do not typically adjust their technical and extension services to include ICTs in the early stages of development, and this limits the impact of these technologies on final users, i.e. farmers. Use of these technologies is confined primarily to management and administration tasks within ministies or agriculture. It is the technical staff in the areas of research, extension services, training and marketing, for example, who are most aware of the needs of final users and who have the greatest capacity to integrate ICTs into the services they provide; thus, limiting their access to ICTs reduces their impact on the agriculture sector.

To boost the impact of ICTs on end-users, public agriculture institutions need to work simultaneously on two fronts: in-house training in the use of these technologies by public officials, and integration of ICTs in the services provided to the agriculture sector. In the first case, a digital literacy policy is needed at all levels to ensure that the staff of public agriculture institutions has the skills to work with ICTs. In the second case, these institutions must progressively introduce ICTs into their technical support and productive development work with farmers, and this means revising the methodologies used in extension services and technical assistance and introducing ICTs wherever possible. Moreover, as e-government develops, public agriculture institutions should have a goal of computerizing procedures and transactions for farmers and making sure that the services actually demanded by producers are available at their institutional web pages.

The existence of e-government strategies and digital agendas does not by itself guarantee that initiatives will have an impact on the agriculture sector. Without mandatory standards and rules governing the use of ICTs in the different activities of public agriculture institutions, many efforts will be at odds with the national strategy and will moreover generate duplications and lower returns on the resources invested. Thus, given the need to generate comprehensive and articulated strategies for promoting ICT use at the national and, in some cases, the supranational level, institutional coordination bodies are needed to facilitate the definition of joint strategies, to articulate activities, and to take advantage of institutional synergies.

I. The evolutionary approach applied to ICT and agriculture technological systems in Latin America: a survey

Mônica Rodrigues

A. Introduction

The evolutionary approach to economic systems places innovation at the centre of the analysis of economic change (Cimoli and Dosi, 1995, Metcalfe and Saviotti, 1991; Silverberg et al, 1988; Dosi, 1984). According to this approach, the possibility of generating complementary exchanges between a complex system (the whole economy or a specific sector) and the environment (for instance, the social/institutional background or the conditions generated by the technological development of other sectors) leads to qualitative changes in the system and therefore to its evolution. At the same time, these exchanges create increasingly complex systems as variation (in technologies, products, institutions, etc.) also increases. In the evolutionary approach, the generation of variation is a deliberate process which –together with the selection mechanism that takes place in the market and with other central features of complex systems such as path-dependence and irreversibility– determines the performance of sectors and nations (Cimoli and Dosi, 1995, Arthur, 1994; Dosi, 1982; Dosi and Metcalfe, 1991).

These characteristics of complex systems –path-dependence and irreversibility– taken as central in the evolutionary approach, affect the way time shapes the results of the innovation process. Decisions, as well as initial conditions and random alterations that take place along the innovation path, influence the way a technology is introduced, develops and disseminates. History and time, and not only decisions, thus matter. In this sense, the timing of decision-making about the creation, adoption or diffusion of a new technology is not neutral, but affects the way the new technology (and other ones) evolve and develop. Therefore, in order to avoid falling into the trap of being locked into unsuitable patterns of development, nations need a strategic view of different sets of technologies and the way they evolve together (Faber and Frenken, 2009). In the case of Information and Communication Technologies (ICTs), due to their current omnipresence in economic activities and society in general, their impacts are numerous and hard to follow. Moreover, their potential impact on the performance of the economy as a whole justifies the design and implementation of policies that consider the development of ICTs together with other technologies (Cimoli and Correa, 2010).

In opposition to neoclassical economic theory the evolutionary approach embraces complex dynamics, historic-institutional contexts and interactive learning processes as core elements in economic change analysis (Nelson, 1992; Spielman, 2005; van der Bergh and Stagl, 2003; Allen and Strathern, 2005). According to this approach, the creation of knowledge and innovation occurs when competitive or collaborative interactions (e.g. production-consumption, technology-preferences, behavior-institutional, etc.) take place among agents, markets and institutions. Economic and technological changes are thus seen as complex, reactive and unpredictable processes since individuals, firms and institutions evolve not alone but in interaction with other agents and responding to changes in their environment (Mckelvey, 2002; Kallis, 2007).

There tends to be a trade-off between the complex view of economic systems adopted by the evolutionary approach and the mathematical formality of most economic models. In spite of recent valuable advances in systematizing complex dynamics through both numeric and descriptive models, some challenges remain, including the endogenous representation of history (and local-specific forces) –a crucial topic in understanding the evolution of institutions and economic systems– and the potential use of these models for policy-making purposes (Malerba, 2006; Malerba et al, 2008; van der Bergh and Stagl, 2003; Lee and Saxenian, 2008).

In this chapter the evolutionary approach to economic systems is used to analyze how the technological paradigm generated by the ICT revolution can impact a set of more traditional technologies in agriculture, particularly in Latin American countries. The case-study methodology adopted here allows us to discuss some pertinent questions currently found in the evolutionary literature such as the nature of technological interactions, the role of information and knowledge in evolution and the way institutions must evolve in response to changes in technological systems. Finally, it is important to note that a dynamic bias is present in the analysis since case studies are selected from countries and institutions that have played an active role in incorporating ICTs into agriculture over the past few years.

B. The evolutionary approach to technological systems and paradigms

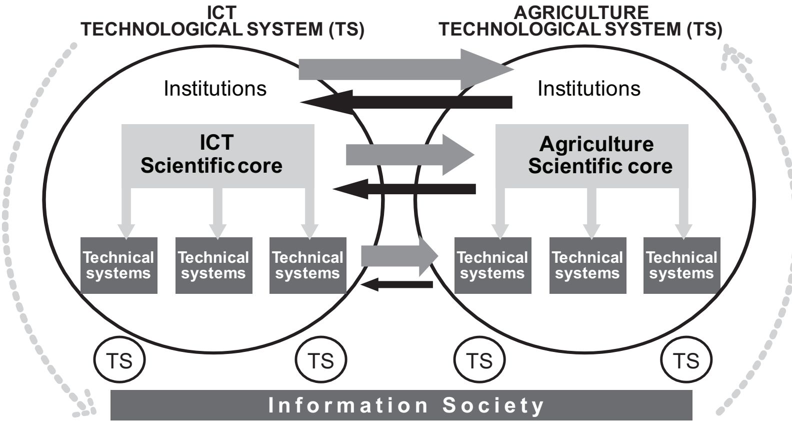
A technological system is usually defined as a multidimensional network of public and private organizations interacting non-linearly in a given historic context. The economic analysis based on technological systems highlights, besides market exchanges, the pervasive non-market interactions among economic agents that explain an important part of the innovation-led growth (Carlsson, 1997; Cimoli and della Giusta, 1998; Cimoli and Dosi, 1995: Cimoli, 1998; Cimoli, 2000). This kind of analysis also draws attention to the role of institutions in economic development, especially those that support innovation (R&D and educational systems, technical infrastructure, technological policy, etc.). It is thus essentially distinct from the more conventional industry analysis centered on economic interactions taking place in markets and governed by prices. Examples of economic analysis based on technological systems in the literature include the national innovation systems framework (see, for instance, Freeman, 1995), technological clusters analysis (Porter, 2000) and the sectoral innovation systems approach (Malerba, 2006; Malerba et al., 2008). Common features of technological systems highlighted by these authors include: (a) a multilayered, heterogeneous structure of open subsystems interacting with each other; (b) a sort of hierarchy among these subsystems based on their contributions to the creation of knowledge and thus to the change of the whole system; (c) a focus on knowledge and competence flows rather than flows of ordinary goods and services; and (d) the existence of a context-specific institutional dimension accounting not only for regulation aspects, but also for implicit norms and behaviors of private agents.

In this chapter agricultural technology systems are defined in terms of four main building blocks –a hard core of scientific knowledge, a set of technical subsystems, the market and the institutional interface– organized around a set of rules, routines and norms which provide the platform for the coordination of collective actions among them (see, for example, Leoncini et al., 1996; Autio and Hameri, 1995; Lee and Saxenian, 2008).These building blocks are open subsystems subject to evolutionary forces such as path-dependence, irreversibility and lock-in, interchanging goods and services and, what is more, competencies and knowledge (see figure I.1). The evolution of agricultural systems is determined by the accumulation of knowledge in its four building blocks and by the transformation of this knowledge in market performance. Moreover, since these building blocks are open subsystems, the dynamic interactions among them are crucial to conduct the whole system along an evolutionary path. Therefore, even though the emergence of the ICT paradigm tends to be more directly associated with transformations in the scientific hard core, it actually has the power to affect the evolution of all building blocks and the interactions among them due to its impact on communication, learning and innovation processes.

The heterogeneity of subsystems and the capacity of agents to influence each other and to learn and adapt to the changing conditions of the system are necessary conditions for evolution to take place (Mckelvey, 2002). The evolution of technological systems is driven by the flow of knowledge and technology within and between systems through transfer and diffusion mechanisms. The acceleration of evolution at the level of economic agents is promoted by the competition and interactive learning within the subsystem to which they belong as well as with other layers of the technological system. Transfer and diffusion mechanisms as well as competition and learning processes in virtually every technological system have been recently transformed by the emergence of the ICT paradigm[1]. Moreover, each paradigm shapes and constrains the rates and direction of technological change irrespectively of market inducements; that is, when a paradigm is in force regularities and invariances in the pattern of technical change can be observed even under different market conditions (e.g. different relative prices) (Cimoli and Dosi, 1994). Despite these regularities, the ways a paradigm interacts with national innovation and regulatory systems – shaped by country-specific institutions and policies – give rise to a considerable variety of outcomes (Cimoli and Porcile, 2009).

1 According to Dosi (1982), a technological paradigm is a model for the solution of selected technological problems, thus in itself highly selective regarding the whole range of technology choices available in a specific context.

Figure I.1
ICT and Agriculture Technological Systems



Source: Prepared by the author.

In the age of the information society most activities are becoming knowledge-intensive. On one hand, the incorporation of ICTs into economic activities comprises a paradigmatic change in the way things can be done, with an impact not only on productivity, costs and value generation but also on market structures, organizations, institutions and strategies. On the other hand, the accumulation of data and information and its organization and dissemination have a potentially positive impact on the processes of learning and innovation, as well as on the risk management, resilience and sustainability of different economic activities, including primary and traditional industries. Therefore, due to their potential to accelerate evolution in different technological systems, ICTs have proved to be more than a technological investment; they are a strategic tool for development.

Gago and Rubalcaba (2007) describe the ICT role in the evolution of technological systems as both *agents* in ICT-oriented innovative activities, *drivers* enabling ICT-intensive innovations, and *facilitators*, in the sense that they make information and knowledge flows more efficient. In this chapter the role of ICTs in the evolution of agricultural technology systems is analyzed from an evolutionary perspective, considering the emergence and evolution of the ICT paradigm and its impact on agricultural systems. Case studies are presented for different ICT-based technological trajectories coevolving with agricultural systems. Both technological trajectories and paradigms describe the "ways of doing things" in agricultural systems, but at different levels; the trajectory being more specific, a kind of subparadigm of the ICT paradigm applied to agriculture. It is not the purpose of this chapter to cover the whole variety of ICT-based technological trajectories in agricultural systems. We instead aim to highlight some remarkable experiences that allow us to illustrate the interactions between ICTs and agriculture in the frame of an evolutionary approach.

1. ICT paradigm, ICT-based trajectories and agricultural technology systems

Human intervention in the natural environment gave rise to agriculture as an economic activity. Improvements in the management of agricultural resources have always been based on observation, the compilation of data and the use of information to enhance knowledge about natural cycles and their response to human action. Different methods and technologies –in a wide sense– have been used in agriculture throughout history to collect, manage and disseminate data and information. Most technological advances have been diffused in this sector through traditional methods of communication, cultural heritage and social change. Over the past few decades, however, the emergence of a new wave of technological innovations headed by ICTs has changed the way natural resources can be managed, transforming agriculture.

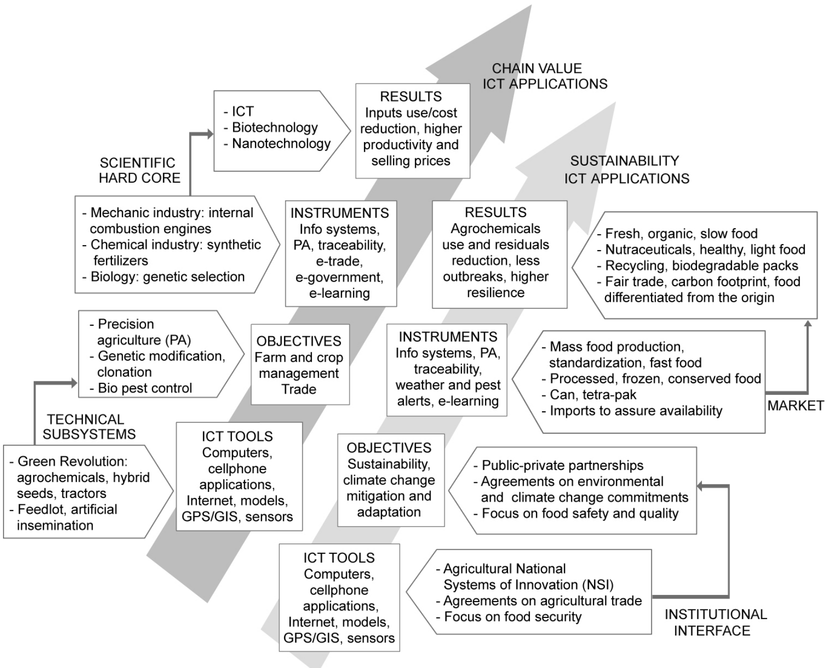
Current ICT-based trajectories in agricultural systems can be delineated once we have an idea of the possible uses of ICTs in agricultural activities. ICTs enclose a set of techniques and scientific methods to make more efficient and effective the way individuals create, use, manage and disseminate data. Recent advances in ICTs allow gathering, accessing, transferring and transforming massive amounts of data in an increasingly efficient and inexpensive way, overcoming some of the former physical and spatial limitations on the exchange of ideas and the improvement of knowledge (Pérez et al, 2006). Current and potential applications of ICTs in agriculture are vast. They include many emerging areas like precision agriculture, traceability, food safety and food security, remote diagnosis of plant and animal diseases, data gathering through georeferentiation and plant architecture, integration and analysis of assorted information, among others. Moreover, there is also an enormous unsatisfied demand in the rural areas of most developing countries for ICT services, currently limited by the low level of connectivity of these areas.

In order to systematize the whole set of potential and current uses of ICTs in agriculture we classify them according to their main objectives in chain-value-rise technologies and sustainability-boost technologies (Rao, 2007). Figure I.2 illustrates the evolution of agricultural systems around these two sets of technological trajectories; the first linked to ICT-based technologies that increase value in food-chain; the second regarding ICT applications that help strengthen sustainability in agriculture. Recent key changes in the agricultural system respond to an increasing international division of labor, a new organization of the value chain activities, the redefinition of the role of public institutions and policies and the globalization –paralleled by a growing product differentiation– of food consumption. Among other technological, economic and social forces, the spread of ICTs throughout the whole agrifood chain, but especially in innovation and logistic activities, has helped promote most of these trends.

According to Pérez (2008) product differentiation in primary and traditional industries has been made possible by flexible, local industrial developments associated with global network interactions, representing an opportunity for developing countries to have access to higher value international markets and to expand capabilities in upstream and downstream sectors. Pérez argues that product differentiation and pervasive technological paradigms like ICTs are transforming the prospects of primary industries towards more dynamic, knowledge-intensive activities. For most developing countries highly specialized in primary activities, these prospects represent new "windows of opportunity" for technological change, but taking real advantage of them implies relying on formerly built competencies and at the same time actively constructing and diffusing new, mostly ICT-based, capabilities.

Figure I.2 also shows the potential results of ICT-based technological trajectories in agriculture. The most obvious impacts of ICTs on agriculture are related to improvements in productivity, reduction of costs and increasing value generation. Reaching at least one of these objectives is usually the bottom line for ICT adoption. In agriculture, yield increments can be achieved due to better land management, the proper use of inputs and timely reactions to climate and pest risks, among other factors. Cost reductions can result from both getting better prices in buying inputs and selling products or as a consequence of making communication and procedures easier and cheaper, thus decreasing transaction costs. On the other hand, value generation is a more indirect measure of subjective valuations made by consumers of a particular product. These three dimensions –productivity, costs and value generation– have been soundly transformed by ICT applications throughout the agricultural value chain.

Figure I.2
ICT-based technological trajectories and the evolution of agricultural systems



Source: Prepared by the author based on Pérez (2001) and Rao (2007).

A less obvious result of ICT use in agriculture regards the positive impact of information on risk management. Contrasting with manufacturing and services activities, agriculture is a more risky activity due to its dependence on natural resources and wheather conditions, its remoteness, which makes access to information time-demanding and expensive, and the seasonality of its production and perishability of its goods. Agricultural input and output markets also tend to be concentrated while primary producers are numerous, dispersed and barely organized, thus susceptible to manipulation and exploitation. The intensive use of relevant and timely information promoted by ICTs has the potential to reduce risk in agriculture in at least two ways. First, it supports a more efficient and sustainable use of natural resources, increasing the resilience of this activity to climate varibility and other natural risks. Second, it increases value creation and capture at the primary production stage, since producers can have access to better and more opportune market information on prices and demand and supply trends.

The strategies of firms regarding ICT define the diffusion paths of ICT-based technologies in agriculture. These strategies are not independent either from what other firms do or from the technological, institutional and market environment they face, that is, from the evolution of the agricultural system. This systemic approach for technology adoption and diffusion aims to explain the evolution of ICT-based trajectories by means of the complex relationships among the diverse actors operating in the agricultural system, their processes of learning and the evolution of market and non-market institutions (Spielman, 2005) as opposed to the traditional theories of technology diffusion in agriculture, which tend to associate the adoption of new technologies to the economy on the use of the scarcest or the most costly input (Hayami and Ruttan, 1985).

The systemic approach seems more appropriate to analyzing the diversity of situations present in Latin America and in developing countries in general, where the presence of the most advanced ICT-based technologies tends to be restricted to a few dynamic pools while the rest of the sector is scarcely informed of ICT prospects or what these technologies are about.

C. ICTs and the evolution of agricultural systems: theoretical issues and illustrative case studies in Latin America

Developing a knowledge-intensive agriculture means dealing with at least three seemingly opposed objectives: contructing a globalised yet differentiated and sustainable activity. All these characteristics demand access to massive amounts of information and thus make the incorporation of ICTs critical in virtually all segments of the agricultural production and distribution chains. As a result, the evolution of agriculture is now decisively affected by the way ICT supply evolves and by the effectiveness and efficiency of ICTs incorporated, not only in technical equipment, but in a broader way in investment, marketing, institutional and even educational and cultural activities linked to agriculture and rural development.

Several countries in Latin America have constructed strong competencies in primary industries, including agriculture, as a strategy to reinforce their historical comparative advantages in these areas. In recent decades, however, the emergence of some technological paradigms –ICTs, biotechnology, nanotechnology (CEPAL, 2008; CEPAL-SEGIB, 2009; Cimoli and Porcile, 2009)– permeating different industries challenged the former structures and systems. In order to benefit (or even to keep their role) in some of the new combinations of resources created by these paradigms –what Pérez (2008) called "windows of opportunity"– primary and traditional industries in developing countries had to invest in building new capabilities. The result has been an acceleration of evolution in traditional industries, including agriculture, to cope with the new forms of competition and cooperation.

Unlike the trends observed in primary industries, capabilities in ICTs have never been historically present in Latin American countries; this does not imply, however, that developing countries in general cannot benefit from ICT advances made in other, mostly developed economies. The construction of local, complementary capabilities to adopt and adapt ICTs to indigenous conditions is crucial to determine its speed and path of diffusion, as well as its economic and social impacts on the recipient countries. Activities with a considerable local bias like agriculture are particularly harmed when the corresponding internal ICTs needed capabilities are not present. Analogously, some specificities of agriculture as a user of ICTs –subject not only to strong local forces but also to the great heterogeneity and dispersion of agents– impose singular requirements on ICT suppliers.

This section aims to discuss these and other emerging questions in the evolution of ICT-based technologies and agricultural systems, using case studies in Latin America to illustrate specific trends and issues.

Agriculture accounts for around 5% of Latin America's GDP, with a high degree of variability among individual countries, going from around 3% in Mexico to more than 23% in Paraguay (CEPAL, 2011a). The participation of agriculture in the labor force is higher, ranging from less than 9% in Venezuela up to more than 30% in Bolivia, Guatemala, Honduras, Nicaragua and Peru (CEPAL, 2011b). This high dispersion, along with the strong heterogeneity of Latin American agriculture in terms of crops, productivity, technological systems and land distribution, among other factors, imply that a large range of situations and potentials can be found for the use of ICT-based technologies in agriculture.

We selected only a few examples to demonstrate the potential of ICTs to accelerate evolution in agricultural systems. We also try to illustrate through these examples some of the questions that arise when applying an evolutionary framework to the analysis of the technological change in a traditional sector. Three major issues are addressed: (1) how the singular requirements imposed by agriculture on ICT suppliers shape the interactions between ICTs and agricultural systems, (2) how some technical and social variables can affect the intensity of ICT adoption in agriculture and (3) the central role of the institutional interface in shaping evolutionary processes.

1. Specificities of Latin American agriculture and its interactions with ICTs

The concept of niche markets is used in this section to explain the development of the two main trends identified regarding ICT-based technological trajectories in agriculture. This concept is central to understand how the interactions between consumers and producers can promote technological transitions. Niche models have been used in evolutionary economics to explain how heterogeneous consumer preferences accelerate evolution by allowing new technologies to develop within small consumer groups before they are introduced in the mass market (Faber and Frenken, 2009; Malerba et al, 2007; Schot and Geels, 2007; Windrum and Birchenhall, 2005; Smith, 2003). Consumers are subject to bounded rationality and develop routines and imitation mechanisms in order to deal with information, knowledge, time and cost constraints. It is the deviation of some consumer groups from prevalent consumption patterns which generates niches and supports the emergence of alternative technologies.

Niche models are particularly useful to explain the appearance (and in some cases the posterior prevalence) of environmentally friendly and other non-traditional technological trajectories. This approach brings the interaction between demand mechanisms and technology creation to a central position in explaining evolutionary processes and leads to the conclusion that learning processes are not only about technology but also about its articulation with user preferences and the required changes in the regulatory framework.

Niche market models highlight the role of demand differentiation and of interactions between consumers and producers in the emergence and especially the diffusion of new technologies. Malerba (2006) and Benbya and McKelvey (2006), both studying innovation and evolution in the ICT industry, concluded that a convergence of different technologies, demand and industries and a process of knowledge integration are currently taking place due to the emergence of ICTs, biotechnology and other pervasive new technologies. According to Malerba (2006) innovation in ICTs is affected by demand and standards while technological systems in general are being transformed by some major trends promoted by ICTs, particularly the integration of previously separated knowledge and the new relationships involving producers, consumers and non-firm organizations.

Examining niche markets reveals interesting insights regarding the analysis of the two ICT-based technological trajectories in agriculture identiflied above. First, the niche approach is considered here an appropriate framework to study the transition from more conventional technologies to ICT-based ones and their diffusion path in agriculture. Second, within some market and institutional boundaries, we can observe the dynamic interactions between a traditional, mostly technology-user activity like agriculture and ICTs. These trends are illustrated with the analysis of two emerging technological trajectories in Latin American agricultural systems: precision agriculture in Argentina and agribusiness software in Brazil.

a. Precision agriculture in Argentina

The first case study refers to precision agriculture (PA), a set of techniques greatly dependent on technology supply advances, but whose evolution is strongly linked to market and regulatory frameworks as well. PA alludes to the fine-scale management of the inherent variability of agriculture (Zhang et al., 2002), allowing to rationalize the use of inputs due to a better knowledge of the site-specific needs of each crop. ICTs are pervasive in PA systems at different stages of the production cycle: a) before planting, by integrating lab tests and maps and programming planting equipment); b) during the growing season, by compiling, organizing and comparing observations on the crop being grown as well as programming irrigation and the application of fertilizers, pesticides and other chemicals); and c) during harvest, by monitoring yield and building yield maps. Geographic positioning systems (GPS), geographic information systems (GIS), computer-guided controllers and sensing technologies for automated data collection and mapping are widely used, each one performing a role in compiling agricultural data and integrating them into farm management decisions.

Lambert and Lowenberg-DeBoer (2000) revised more than a hundred articles which had reported economic results of PA based on either simulated responses or actual field tests, revealing higher profits in most cases. Regarding environmental impacts, Bongiovanni and Lowenberg-Deboer (2004), in an extensive literature review, find that PA technologies can help make agriculture more sustainable due to a more judicious use of agro-chemicals[2]. The possibilities created by PA for maintaining or increasing yields while rationalizing the use of agrochemicals are leading regulatory organizations to adjust (to a lower level) the thresholds of accepted residuals in locally produced and imported foods. This regulatory reform made possible by ICT agricultural applications is transforming agricultural production and institutions in many countries, including some Latin American economies that actively participate in international agro-food markets.

Impacts in the opposite direction –from agriculture to ICTs– are also observed, since in some situations local, niche-specific conditions in the agricultural systems can shape and accelerate the evolution of PA technologies. The introduction and evolution of PA in Argentinean agriculture is an interesting example. Unlike most agricultural exporters in Latin America, Argentinean comparative advantages can be found in extensive annual crops (mainly soybeans, wheat and maize), which are among the most appropriate for the adoption of PA systems. Lowenberg-Deboer (1998) detected other specific, systemic determinants for the introduction of PA technologies in Argentinean agriculture. Characteristics like the large average size of farms, a longer (compared to the US) harvest season, an important natural soil variability and the prevalence of custom operators in farm management and equipment operation (a particularity of Argentinean agriculture in Latin America, are identified as some of the

2 According to Bongiovanni and Lowenberg-Deboer (2004), PA benefits to the environment come from a more targeted use of inputs, which reduces losses either from excess applications and due to nutrient imbalances, weed escapes, insect damage, etc. Other benefits include a reduction in pesticide resistance development. The article revises studies on the impact of site-specific management of fertilizers (N and P), herbicides, insecticide and water on the environment. In almost all cases these studies show, through different techniques and models, positive results for PA technologies (variable-rate application of agro-chemicals and water compared to a uniform-rate) in terms of savings in inputs use, reduction of negative environmental impacts, higher profitability, better weed control, and, in some cases, increases in yields and more accurate predictions. Revised studies refer mainly to the United States, but experiments in Canada and Europe (UK, Germany and Denmark) are also presented.

major determinants of the much higher use of PA in Argentina, when compared to other developing countries.

Routinary farm operations affect the potential of PA adoption in at least two ways: they allow for a more intensive use of PA equipment, making its adoption cheaper, and they make precision data more valuable for farmers that do not participate in crop duties and cannot directly observe crop conditions and yield variability (Lowenberg-Deboer, 1998). As a result of these favorable conditions along with the implementation of suitable policies, today Argentina ranks second in the world (first in Latin America) in the number of PA monitors in use and fifth in cultivated area under PA systems, according to a study carried out by the National Institution for Agricultural Technology (INTA Manfredi, 2008). However, due to the high land concentration in that country and to the fact that PA systems are almost exclusively present in large farms, these numbers still correspond to only 5% of Argentinean farmers. The national production of PA systems flourished in Argentina after the exchange rate devaluation that took place in 2001 (which made imports of PA equipment much more expensive), promoting the emergence of small enterprises producing not only for the internal market, but for regional markets as well.

b. Agribusiness software industry in Brazil

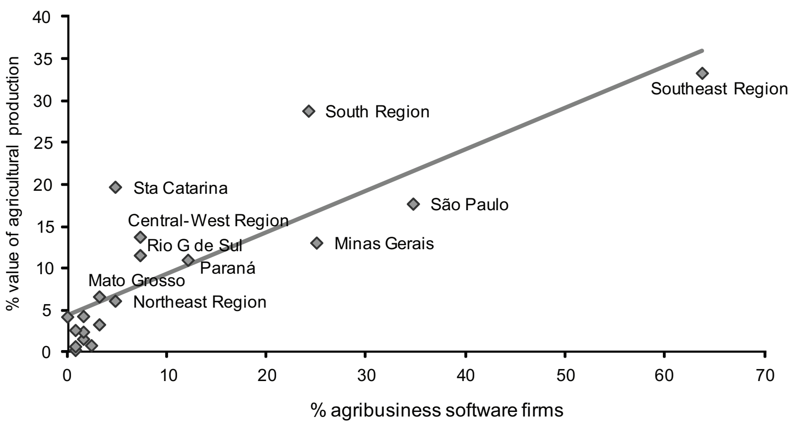
The second case study regards information systems management, a wide area in the ICT paradigm. The basic idea is to use accumulated data for decision-making, typically through the construction of models or simpler parameterized rules of decision. Several ICT-based technologies are used in this fieldwork for data gathering, database management and modeling. In the case of agriculture, information systems usually have an important local content, demanding specific ICT tools and services. Even though generic technologies and models are used, local adaptations and expertise can be required, demanding in some cases a strong interaction between end-users (farmers) and the developers of models and ICT applications.

In some areas of Brazil the development of software to address specific agribusiness needs is a newly flourishing enterprise. According to a project carried out by the National Institution for Agricultural Research (EMBRAPA), even though the agrifood chain still represents a less important client for the software industry, in the last few years the market for agribusiness software increased 250%, a much higher rate compared to the software market in general. Firms producing software for the agrifood chain represent 2.5% of the total number of software firms in Brazil, a still low participation taking into account the national importance of agribusiness (including agriculture, agro-industry and related sectors), which represents almost 25% of Brazil's GDP.

The regional distribution of agribusiness software firms in Brazil shows an important correlation with the vigor of national agriculture (see figure I.3): 88% of them carry out activities in the Southeast and South regions, where the most dynamic agriculture takes place (Mendes et al, 2010). Moreover, half of the firms –most of them small enterprises– are spread over only ten municipalities where large public universities conduct research and extension programs linked to both regional agriculture development and business incubators (see figure I.4). The results of a research conducted on these firms also reveal that the most relevant barriers to entering the agribusiness software market are the lack of specialized workers and the difficulty in obtaining the required specific knowledge about agribusiness markets (Mendes et al, 2010).

Figure I.3

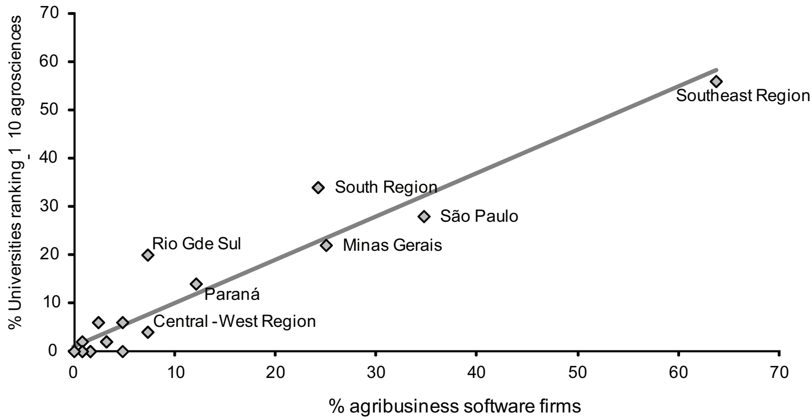
Location of agribusiness software firms in Brazil according to the value of agricultural production



Source: Own elaboration based on Mendes et al (2010) and IBGE .

Figure I.4

Location of agribusiness software firms in Brazil according to the ranking of agroscience universities



Source: Own elaboration based on Mendes et al (2010) and Brazilian Ministry of Education .

Therefore, the conditions for the development, location and structure of the agribusiness software industry in Brazil, a niche market within the ICT industry, decisively depend on the evolution of the agricultural system in the country. The existence of a critical mass of dynamic clients and of public research programs linking agricultural development to new (small) business opportunities play a critical role in the creation of local opportunities for the software industry. Moreover, due to the barriers to entry represented by the requirements for specific agricultural knowledge, software firms tend to be located close to institutions with research centers and human resources formation programs linked to agriculture. The lack of specialized knowledge and human resources can also be (at least partially) offset by strengthening user-producer relationships, which could help explain why locating near potential users, in dynamic agricultural zones, is an important strategy for agribusiness software firms.

2. Organizational requirements and social factors conditioning ICT adoption in agriculture

ICT diffusion is a non-linear process. ICT adoption by firms is the result of a complex process that involves different stages, the transition from one stage to the next being the result of efforts made in complementary organizational and technological resources. In the first stages, ICT infrastructure (connectivity, hardware and software, content, storage and process capacity, etc.) is the main focus. As the aim of ICT adoption improves from the simple access to and sharing of contents to a more development-oriented strategy, the complexity of needed resources and of interactions among them increases in a non-linear way. Therefore, firms progressing in the use of ICTs must enhance not only their technical attributes but also, increasingly, their operational, management and organizational structures in order to cope with these escalating needs.

Institutions, organizations and learning processes need to adapt to the use of the new technologies. Pérez (2008) stresses that retardings in those changes slows down diffusion of the new technologies and thus the expected rise of productivity and other economic benefits in user sectors. This retardation varies according to the flexibility and accumulated capabilities of organizations, industries and institutions which allow them to adapt to the requirements of the new technologies. In order to understand how the potential economic impacts of ICTs on user sectors are conditioned by the accumulated capabilities of organizations and institutions it is useful to be aware of the differences in the concepts of data, information and knowledge.[3] These issues are higly relevant for ICT adoption in Latin American agriculture, given its heterogeneity.

By potentially increasing both the availability of data and the ability of agents to interact with that data to create additional knowledge, ICTs have the power to improve not only the economic benefits but also the learning processes and accumulated capabilities in user sectors. To take advantage of the learning opportunities created by ICTs, though, agents first must develop appropriate and sufficient capabilities to discern data in the world, to identify useful information and to use it to improve their knowledge base. Indeed, the inability to discern which information is useful among the huge (and permanently increasing) amount of available data and to understand how this information can improve productivity

3 According to Boisot and Canals (2004), data originates in differences in physical states-of-the-world discernible (in terms of space, time, and energy) by agents. Agents are bombarded by stimuli from the physical world, not all of which are discernable by them and hence not all of which are recorded as data for them. Information constitutes those significant regularities residing in data that agents attempt to extract from it. What constitutes a significant regularity, however, can only be established with respect to the individual dispositions of the receiving agent. Information, in effect, sets up a relation between in-coming data and a given agent. Finally, knowledge is a set of expectations – held by agents and modified by the arrival of information – which allows an agent to act in adaptive ways in and upon the physical world. To summarize, we might say that information is an extraction from data that, by modifying the relevant probability distributions, has a capacity to perform useful work on an agent's knowledge base and on its capacity to adapt to a changing world.

and bring other economic benefits might disqualify ICTs as a potential investment to firms.

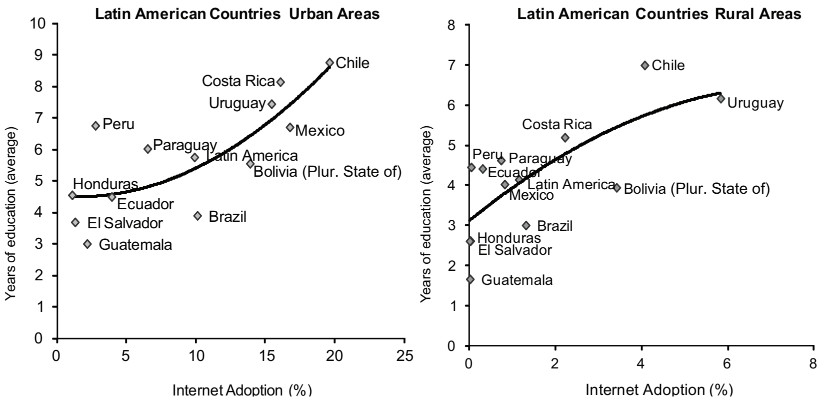
In the case of agriculture, several studies have identified the potential barriers to a wider adoption of ICTs, particularly in developing countries (Bhavnani et al, 2008; Caspary and Connor, 2003; GFAR, 2008; Jensen, 2007; Meera et al, 2004; OECD 2009a and 2009b; Rao and Malhan, 2008; World Bank, 2009). The barriers are basically twofold. On the supply side, connectivity in rural areas is still limited, the cost of hardware and software can be prohibitive for most farmers and the usefulness of on-line content for agricultural producers is often unclear. On the demand side, the opposition of farmers –especially the older and less educated ones– to incorporating new devices in production and farm management is pointed to as one of the major reasons for the low use of ICTs in agriculture. Both, supply-side limitations regarding the usefulness of content and demand-side restrictions due to the resistance of farmers can be transformed by a richer interaction of agents with data.

Even though formal education is not the only determinant of the ability of users to properly transform data and information into new knowledge, it is the critical first step. Among Latin American farmers there is an enormous educational deficit that has only recently begun to be addressed by appropriate public policies. As a result, education is still a restriction on the adoption of ICTs by farmers (see figure I.5).

Since farmers with low levels of education cannot properly evaluate ICT benefits to agriculture, ICT adoption is discouraged and practical evidence on the economic and environmental benefits of these technologies becomes even more sporadic, reinforcing farmers' uncertainties. In Latin America, workers in agriculture have the lowest educational level amongst all the economic sectors, limiting their ability to properly operate complex agricultural technologies. Farmers' insecurities associated with aging are another relevant issue: for Mendes et al (2010) the cultural resistance and educational limitations of elderly farmers in Brazil are so decisive to ICT adoption that they argue that a significant increase in ICT use in agriculture can be expected in the next decade, once a new generation of managers takes over.

Figure I.5

Internet adoption by years education average of agricultural workers, around 2008



Source: The author based on household surveys data.

In Chile, based on information provided by the 2007 agricultural census, we calculated the probability of Internet use in farm duties associated with a set of variables representing management skills, technology level and human resources capabilities. The results of the Logit model (see table I.1) confirm the impact of age and education on ICT adoption: younger, better-educated farmers have a higher probability of incorporating these technologies into their functions. The model also shows the importance of other variables in determining Internet adoption by farmers: characteristics of the enterprise such as the destination of production (exports, agro-industry), custom management, the association with agro-tourism and technology attributes such as fertirrigation and organic production are all connected to a higher probability of adopting Internet use.

Zhang et al (2002) list some additional limitations to ICT adoption in agriculture very common in developing countries: the lack of agronomic and ecological expertise to adapt ICT-based technologies to local agricultural conditions, the relatively high training and consultancy costs and the risks associated with climate and economy changing events. In these countries the call is still for the detection of situations in which ICT use in agriculture is economically feasible and for the recognition and measurement of the social and environmental impacts of these technologies.

Dobermann et al (2004) point out that even though high costs, unavailability of many complementary technologies and services, and uncertain benefits seem to preclude any possibility of a massive use of ICTs in agriculture in developing countries, the basic purpose of ICTs –to provide pertinent and timely data to reduce uncertainty– should be viewed as essential to accelerating change in these countries. For this author, the need for useful data is actually greater in developing countries, mainly due to a stronger imperative for change and a lack of conventional support to promote change.

The challenge to ICT adoption in agriculture seems to still lie in overcoming issues of scale and uncertainty and finding meaningful ways of delivering data to farmers, making them also more able to transform the data into useful knowledge. Interestingly, ICTs can help accomplish these last objectives too –via both a wider access to and better use of data and through the improvement of learning processes– providing that the initial barriers to the use of these technologies can be overcome by appropriate policies.

Table I.1

Results of a logit model to the probability of Internet use in chilean farms

Variable	dy/dx	Std.Err.	P>|z|
Education (at least secondary)[a]	0.048139	0.00096	0.000
Age under 45[a]	0.001162	0.00051	0.024
Manager living in farm	-0.01122	0.00054	0.000
Male[a]	0.000811	0.00047	0.084
Income from agriculture (%)	-5.49E-06	0	0.006
External manager[a]	0.027763	0.00141	0.000
Access to promotion programs[a]	0.003622	0.00065	0.000
Access to loans[a]	0.002242	0.00056	0.000
Engaged in producers' association[a]	0.007841	0.00057	0.000
Other activities: rural turism[a]	0.026207	0.00435	0.000
Destination of products: exports[a]	0.015619	0.00116	0.000
Destination of products: processing[a]	0.011687	0.00091	0.000
Contract farming[a]	0.004408	0.00094	0.000
Organic farming[a]	0.014853	0.00276	0.000
Permanent crops area	5.43E-05	0.00001	0.000
Total area	2.84E-07	0	0.026
Automatic irrigation[a]	0.009557	0.00114	0.000
Automatic irrigation area	1.09E-05	0.00003	0.673
Fertirrigation[a]	0.006215	0.00133	0.000
Machinery in use	0.001117	0.00005	0.000
Machinery new	0.001015	0.00018	0.000
Plagues/disease integrated control[a]	0.007831	0.00118	0.000
Certified seed[a]	0.002589	0.00056	0.000

Source: Own elaboration based on Chilean Agricultural Census data (2007).
[a] dy/dx for discrete change of dummy variable from 0 to 1.

3. Institutional evolution in agricultural systems and institutional ICT-induced changes: the case of traceability

Institutions have recently gained more importance in economic theory due to an increasing acknowledgement of the bounded rationality of economic agents and of the omnipresence of uncertainty in economic systems. Different theoretical approaches –from mainstream to institutionalism and evolutionism– have placed additional emphasis on the role of institutions, as "rules of the game", in explaining economic performance (Coase, 1937; Hodgson, 2003; North, 1990, 1991 & 1993; Ostrom, 1990 & 2005; Williamson, 1985). This theoretical discussion is nonetheless too far-reaching to be addressed here. In this section we will focus instead on how institutional change can shape and accelerate the evolution of some technologies, and vice versa.

According to Van der Bergh and Stagl (2003), even the evolutionary economic literature has a biased focus towards firms and technologies instead of social and institutional change in analyzing economic performance. For these authors neglecting institutional change implies implementing poor public policies; in fact, they see policy-making to a great degree as designing flexible institutions, capable of learning and adjusting behavior to changes in economic and social systems. Current evolutionary models present causal, usually descriptive explanations of institutional change (Nelson, 2002; Van der Bergh and Stagl, 2003; Funk, 2009). Institutional evolution, like technological evolution, is seen as a process of diversification and selection, in many cases unplanned, in response to changes in other parts of an open system or in other related systems.

For Katz (2001) the firm is influenced not just by conventional macroeconomic variables, but also by forces deriving from the highly specific, localized institutional environment in which the firm has to operate: intellectual property rights, sectoral technological agencies and institutions, research universities and banks belong in this particular group of determining factors. Cimoli and Porcile (2009) also highlight the role of institutions supporting technical change in shaping the paths of learning and the observed patterns of industrial structures. For these authors, the literacy and skill level of the workforce, the skills and technical competence of engineers and designers in the mechanical and (increasingly) electronics fields, the existence of managers capable of efficiently running complex organizations and the quality of higher education and research capabilities are all clearly relevant. In that sense, firms and institutions are dynamically linked via input-output flows, knowledge spillovers, complementarities and context-specific externalities.

Institutions are central in determining the impact of new technologies on economic systems. Even when generating increasing returns, a new technology alone has a limited contribution to make to system efficiency. They must be first validated by social selection mechanisms before they can have a systemic economic impact. The market is the selection mechanism for excellence, but institutions also play an important role in this process since they work as macro-level facilitators of (or barriers to) the micro-level strategies of technology innovation and adoption. In this sense, it is common that motivations for the early adoption of new technologies come from sources other than the economic gains perceived by potential adopters, such as regulations and subvention policies. In fact, when potential users are limited in their ability to properly assess the benefits of a new technology –due to either cognitive limitations or lack of evidence about those benefits, particularly in the early phases of the diffusion process– the role of institutions and policies can be decisive in determining its adoption and dissemination. In the case of ICTs, for instance, even though information is recognized as the main source of knowledge creation and a key generator of wealth in modern societies (Boisot and Canals, 2004), valuing ICTs so as to justify making the necessary investments in them demands an extensive understanding of their positive impacts or, alternatively, suitable promotion policies.

Advances in traceability illustrate how the information generated by farmers is being increasingly valued by consumers and organizations throughout the food chain and, at the same time, how this trend alone is not enough to diffuse traceability systems in agriculture. A combined evolution of ICTs, regulations and policies is actually needed to diffuse this technology and to make the most of it. For McMeekin et al. (2006), the use of traceability tools like bar codes and more recently Radio Frequency Identification (RFID) is revolutionizing the way supply chain data is captured and communicated, making it possible to obtain data and interchange them efficiently amongst participants not commonly linked within a traditional supply chain. Traceability also seems to allow improving logistics, mitigating exposure to risks and responding to the growing consumer demand for safer food. In spite of these observable benefits, though, a top-down directive, either mandatory or voluntary, is usually needed in order to diffuse traceability systems in agriculture (see box I.1).

The results of some studies conducted to assess the impacts of traceability systems on the agrifood chain –from farmers to consumers– show how transaction costs are fundamentally altered by the implementation of these systems (Souza Monteiro and Caswell, 2004; Xiaoshuan et al, 2010; Benterle and Stranieri, 2008; Loureiro and Umberger, 2007). Traceability systems also help to add value to food products by enhancing food quality through labeling of experience and credence attributes: this is the case for protected geographical indication foods and other niche markets like organic and fair-trade products, all of them associated with strict traceability requirements.

Regarding the impact on consumers' behavior of the increasing availability of information generated by traceability systems, Loureiro and Umberger (2007), analyzing the US beef market, found that safety and quality labeling increases consumer willingness-to-pay for food. These results confirm firms' perceptions that traceability allows capturing value by differentiating agrifood products through confidence and quality attributes. For Narrod et al. (2009), however, it is not clear that farmers, and particularly small farmers, can benefit from the increasing coordination of food supply chains promoted by traceability, due to problems of scale, access to appropriate technology, rising costs and risks.

Traceability is thus becoming an important tool to help firms manage the information flow about products, improve food safety and quality and support market differentiation. Traceability alone, however, only transfers information along the supply chain. In order to affect quality and safety and thus to make a difference in agricultural systems, traceability systems must be associated with a set of standards and procedures. Only then can these technologies allow agents to capture efficiency gains through improved supply management and to achieve competitive advantage by differentiating foods (Souza Monteiro and Caswell, 2004; Xiaoshuan et al, 2010; Benterle and Stranieri, 2008). The definition of common standards and procedures, a crucial responsibility of regulatory institutions, not only allows attributing specific responsibilities to agents but also provides for interchanging data on traceability among different agents and countries within a supply chain. Finally, they allow integrating databases and information systems on different subjects.

Box I.1

International directives shaping traceability systems in Latin America

Even though traceability is becoming increasingly important in the international arena, diverse national and supranational arrangements, with different stringency levels and public or private accents, tend to coexist. For example, in response to differing consumer perceptions of important food safety and quality attributes, the United States adopts traceability systems mainly regulated by private standards. In the European Union (EU), in turn, traceability is mandatory for the beef sector and it combines, in the case of other agrifood products, a basic public regulation with stricter voluntary private standards (Banterle and Stranieri, 2008). In fact, private systems are frequently more stringent than governmental regulations, becoming de facto mandatory requirements for food suppliers wanting to participate in premium markets. Authorities and producers are willing to increase their food safety standards as far as they believe that the price they get in these markets largely compensates additional costs.

In Latin America, traceability requirements of international markets have affected not only the big regional players in the meat and meat products markets, like Brazil, Argentina and Uruguay, but also non-traditional exporters of high-quality and niche agrifood products. Countries exporting beef and beef products to the EU, for instance, must fulfill mandatory traceability requirements that include the identification and registration of animals and the labeling of derived products in order to ensure a clear link between the final product and the original animal or groups of animals. Due to the importance of the EU beef import market and to the stringency and pioneership of its regulations, these requirements have shaped traceability regulation in many producer countries, at least regarding the beef export firms. Actually, many Latin American countries have different levels of requirements for beef producers according to the market destination: internal or external. Additionally, when they are exporting through some specific retail chains extra constraints can apply.

Source: Prepared by author.

Regulatory and support institutions are central players in shaping the adoption and diffusion path of ICT-based technologies in agriculture. From a evolutionary perspective, however, it is also imperative to consider the impact of the new technologies on institutions, in the sense they are permanently imposing new requirements both in terms of human resources, management capabilities and regulatory and policy capacity. Since ICT requirements are dynamic due to the changing business environment, consumer preferences and ICT technology supply, institutions must be flexible enough to recognize, interpret and react to the evolving ICT needs of agricultural systems. In the case of traceability systems linked to the most developed markets, we can observe in recent years a transformation from passive information tracing to proactive food quality control, that is, from data management to information integration and intelligent decision-making (Xiaoshuan et al, 2010). This calls for agricultural institutions all over the world to develop common standards and regulations in order to make the most of this technology to improve strategic food supply chain decisions.

D. Final remarks

In modern societies, ICTs are ubiquitously used for the generation, management and diffusion of information and knowledge, not only in economic activities, but also in social life in general. In highly heterogeneous societies like Latin American ones, however, the application of ICTs in low-productivity economic activities like agriculture is usually ignored or disregarded due to other development priorities deemed more important. This line of reasoning does not take into account the dynamic effects of ICTs on innovation and economic development, which go beyond their direct and measurable contributions to economic growth. An evolutionary approach to ICTs and agriculture focuses on the dynamic links between these two sectors, considering each one as an essential part of the environment with which the other one interacts and jointly develops.

This chapter strives to contribute to this discussion by addressing, through case studies for Latin America, some of the questions raised when applying a dynamic and systemic approach to the evolution of ICT-based technological trajectories and agricultural systems. Preliminary research presented here shows how agricultural systems have been decisively affected by the availability of new ICT-based technologies over the past few decades and, at the same time, how the evolutionary path of some ICT niches have been shaped by the specificities, regulations and policies of agricultural systems. Further research is needed to more fully evaluate some of the trends identified here, particularly the potential for a development-friendly evolution of ICTs and agriculture and the required support policies to achieve that goal.

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II. ICT adoption and diffusion patterns in Latin American agriculture

Ruth Rama and John Wilkinson

A. Introduction

People often conflate biotechnology and information technology (IT) when discussing new technology paradigms in agriculture; however, these technologies have entered agriculture in decidedly different ways and have had very different repercussions. The application of biotechnology to agriculture laid the foundation for the Green Revolution by developing new seeds, fertilizers, herbicides and pesticides which led to explosive increases in agricultural productivity. It was in essence an inputs revolution; inputs which could be applied within traditional agricultural practices, widely distributed through established marketing channels and made available to large corporate producers as well as small, rural farmers. Bioinformatics —the application of ITs in genomics— has led to further advances in the development of agricultural inputs. Concerns about biotechnology products have provoked controversy and opposition both within agriculture and at the consumption end of the agro-food system, mainly centered around their real or perceived negative impacts on public health, the environment and agricultural sustainability.

Information technologies, on the other hand, are essentially process innovations that have revolutionized the gathering, processing and dissemination of information and data. In combination with modern communication technologies, their impacts are evident throughout the agro-industrial value chain and affect every part of the process, from farm administration and transaction costs, to marketing and agricultural productivity. The adoption and diffusion of information and communication technologies (ICTs) largely depends on the availability of electricity, which is still not universal in Latin America and the Caribbean, and other older technologies. Although initially constrained by limited transmission infrastructure, wireless technologies have opened new avenues for diffusing ICTs. Low levels of technological literacy are still a significant barrier to wider dissemination. In contrast to biotechnology, the greatest concern regarding the ICT paradigm shift in agriculture is that the digital divide —the gap between the technological haves and have-nots— may create even greater socio-economic disparities between large-scale producers and smaller, more rural farmers.

Roughly speaking, there have been four phases in the ICT revolution in agriculture. The first stage featured adopting computers and basic data processing and accounting applications for more efficient farm administration —increased control over inputs and outputs and better financial management. The second phase was the emergence of public and private software developers who began designing specific software for agriculture which have placed new and considerable technical and managerial demands on farmers. The emergence of the Internet defines the third phase. In addition to providing capabilities like real-time technical assistance, the Internet has transformed access to markets and supply chains. The last phase, associated with the use of GPS and GIS systems and the development of precision agriculture, has primarily affected large-scale agriculture because PA requires expensive, specialized equipment and machinery.

Over the last decade —at least— there has been a shift from fixed to portable information-gathering and computational equipment and from fixed to mobile telephony, converging in the emergence of smart phones that combine computing, telephony and the Internet. The motives for ICT adoption have also evolved, from an almost singular focus on efficiencies, to broader public concerns over the issues of food safety and quality and the environment. If precision agriculture best illustrates the potential of ICTs to improve efficiency, these new concerns are reflected in the development of traceability systems. In a similar way, substantive concerns related to the perceived danger of the digital divide have led to a focus on the differential access of large-scale commercial and family farmers to ICTs.

This chapter adopts a spatial approach to analyze ICT adoption and diffusion in the agricultural sector. It includes analyses of the drivers and patterns of adoption and diffusion, the extent of ICT diffusion in LA and the scope of the digital divide in the region.

B. Defining ICTs and sources of statistical information

ICTs are the key component of the current economic paradigm. Worldwide, the ICT sector attracts the greatest share of investment for research and development owing to its dynamism and its supply of essential technology to all areas of the economy. Over the last decade, there has been a systematic effort to harmonize the data on ICTs in Latin America. This initiative has been led by ECLAC, with the creation of the Observatory for the Information Society in Latin America and the Caribbean (OSILAC) as part of a global UN program for ICTs focusing on data harmonization as a precondition for confronting the problems of the digital divide.

The ICT manufacturing sector produces a broad range of products, including electronic components, computers and peripherals, telecommunication equipment, consumer electronics, multimedia equipment and measurement instruments. The ICT service sector, which includes everything from telecommunication services, computer services and software development, to data processing and a wide array of Internet-related services, accounts for the lion's share of economic activity in the sector. In the European Union, for example, ICT services account for 68% of employment and more than 75% of value-added in this sector (EU, 2010).

ICT applications in agriculture include emerging areas such as precision agriculture, traceability, food safety and food security, Global Positioning System (GPS) devices and geographic information systems (GIS) (Moguillansky, 2005). The use of GPS for disease control and the use of e-commerce to lower transaction costs by reducing the role of commercial agents (Aleke et al., 2011) are among the widely varied benefits of the use of ICTs in agriculture.

National statistics on ICT adoption in Latin America specific to agriculture are scarce, with exceptions such as Brazil's and Chile's censuses of agriculture and husbandry. Several sources of information, therefore, need to be combined. Latin American technology and innovation surveys often do not collect information specifically on agricultural enterprises. For instance, the Brazilian Technology and Innovation Survey (PINTEC), produced by IBGE, focuses exclusively on the manufacturing and service sectors. However, such surveys may have some usefulness for analyzing the technological relationships between agriculture and the broader value chains of which it is a part.

Latin American population and housing censuses provide some valuable information regarding the diffusion of ICTs. At the time of this writing (September 2012), the ICT Statistical Information System of OSILAC had compiled 96 surveys pertaining to 17 Latin American countries[4]. Comparisons present some difficulty since such surveys are not conducted in the same years for all countries and the number of common questions is limited. However, an advantage is that most of the surveys offer disaggregated information for urban and rural areas and this information can be analyzed for different sorts of ICTs by income level and other socioeconomic variables.

Agricultural producers may have access to ICTs at many different locations and in different ways. One limitation of the population and housing surveys is that they provide data on the availability of ICTs in households, but not in businesses. With some exceptions, as will be seen below, population and housing surveys do not provide information on the availability of public services. Yet, in developing countries, small agricultural producers are often more likely to access ICTs in public facilities which often serve as focal points for social networks and as centers for acquiring ICT skills (Aleke et al., 2011).

Mexico's Population Census 2010 is one of the few sources that provide information on the availability of public telecommunication services in rural areas. These data are disaggregated by five categories of locality size and by region. This census provides data on the availability of different sorts of public telecommunication and Internet services.

4 http://www.eclac.org/tic/flash/

Again, it should be borne in mind that the information on rural areas provides only a rough approximation for analyzing ICT adoption in agriculture since most of the population surveys do not include information about occupations. The sources discussed in this section, therefore, will be complemented by data from other studies whenever possible.

C. A spatial approach to ICT diffusion in agriculture

Over a century ago, Alfred Marshall wrote that "Every cheapening of the means of communication alters the action of forces that tend to localize industries" (Marshall, 1916, p. 273). The major benefits of agglomeration comprise gains related to the reduction of transport costs. Marshall distinguished three types of transport costs –the costs of moving goods, people, and ideas– that can be reduced by industrial agglomeration (Ellison et al., 2010). The well-known "Marshallian triad" describes the main centripetal forces that impel firms to agglomerate in cities and geographic clusters: first, firms located near suppliers or customers would save shipping costs; second, labor market pooling would allow employees and employers to more easily match; and third, intellectual and information spillovers would benefit all firms in the agglomeration, also making it easier to monitor and manage concentrated activities of different firms.

On the other hand, and particularly relevant for agriculture, immobile factors (land, natural resources) and land rents would act as centrifugal forces, that is, they tend to slow down the process of agglomeration[5] . Even though natural resources endowment can also promote agglomeration, this is certainly limited by the resources' availability and by other forces, among them land rents, labor costs and external diseconomies such as traffic and pollution increasing levels.

Marshall's concepts of agglomeration and the forces that impel firms to geographic concentration have been especially valid since the emergence of ICTs like mobile phones and the Internet, which strongly reduced transport and communications costs and challenged the constraints of geographical distance. These features of the digital revolution have the potential to reshape the existing economic landscape and the incentives for

[5] In the economic geography the distinction between centrifugal and centripetal forces relate to effects on the agglomeration of economic activities: centrifugal forces lead to agglomeration; centripetal forces lead to dispersion (e.g. Krugman, 1998).

firms to agglomerate. The final effect is not clear, however. Some authors have argued that the digital revolution would bring about the "death of distance" and promote development opportunities in remote and economically disadvantaged areas (Grimes, 1992). The impact would not only be felt in the emerging ICT industries, but also in traditional activities that would benefit from improved access to global value chains and new markets (Maignan et al., 2003). Other authors argue that, on the contrary, the digital revolution would lead to an even higher geographic concentration of high-tech economic activities, mostly preventing developing countries and marginal areas to engage in them. The case of Silicon Valley and other ICT clusters are usually presented to illustrate this trend.

Analyzing the impact of ICT on regional planning in Finland, Talvitie (2004) concluded that the spatial consequences for traditional industries that use ICT are not necessarily the same as for the ICT industries themselves. For this author, industries that develop ICT have special requirements regarding location such as the proximity of universities and qualified labor, meaning that these activities are not easily spread but rather concentrated on selected cities. On the other hand, enterprises producing manufactured goods and other traditional sectors can benefit from the possibilities created by ICTs to reorganize their activities and to select their location with a greater freedom. In the case of the services sector, Talvitie (2004) found that the spatial impact of ICT tends to be highly diversified and constantly evolving. The location of financial services and commerce has been soundly affected by transactions made via computers or mobile phones, while public services have been upgraded by online two-way communications between government authorities and citizens. Results have shown savings on time and travelling costs and the improvement of the service standard, especially in small communities and rural areas.

The tension between centripetal and centrifugal forces regarding the location of firms and economic activities, and the changes brought about by the emergence of ICTs, are also affecting the agricultural sector, with heterogeneous impacts on the land-use. Moreover, since ICTs are transforming everyday life in a general sense, they have a broader impact in rural areas, not only linked to agricultural activities. ICTs are indeed on the basis of some of the most important technological, economic, occupational and cultural transformations that have been witnessed in rural areas over the last decades. They are a major driving force on spatial change as well since they give shape to different types of networks that affect the way firms and individuals organize their time, space and other resources. For example, ICT solutions provide firms with the ability to locate their activities where the sources of competitive advantages are –dynamic markets, cheap labor, natural resources and so on– while still managing these activities in a centralized and coordinated way. Emerging working practices such as tele-working allow employees to choose their place of residence with more independence regarding their work place and according to their personal wellbeing criteria, which in some countries has been a stimulus to the reinvigoration of rural areas.

Not only the emergence of ICTs has shaped some central trends on spatial development; spatial dynamics have also affected the adoption and use of ICTs and the somewhat different paths of diffusion of these technologies in urban and rural areas. One of the most important areas of research in this issue relates to the effects of physical proximity and clustering of firms on technology adoption. The epidemic theory of technology diffusion, for instance, tries to explain the acceleration of technology diffusion due to spillovers present in geographic agglomerations. Nonetheless, in the case of ICTs, some theories associate geographic dispersion of the different activities of firms with ICT adoption due to the need to manage dispersed production, processing, marketing and distribution functions. The next section will explore some of these questions in the case of agriculture and agrifood sectors.

It is important to notice that the impacts of ICTs on spatial development and of spatial dynamics on ICT adoption are still mixed and unclear. It is not conclusive whether geographic concentration or dispersion forces predominate when firms adopt ICTs. In principle, both trends are possible and have been empirically observed. Since ICTs bring more freedom to the choice of locations by firms, the outcome depends on how this freedom is actually used (Talvitie, 2004). By the same token, it is not clear if in sectors which tend to have their functions geographically dispersed, such as the ones based on natural resources, stimulus to ICT adoption are higher than in more concentrated industries. Finally, even though rural areas seem to benefit from the new communication and business possibilities offered by ICT, it is inconclusive what effects these possibilities will have in the long run on the future of rural territories. Further research seems to be needed in all these fields to clarify the interaction between ICTs and spatial dynamics and its impact on local development.

1. The "death of distance" and implications for agriculture and rural areas

Whether the trend towards the "death of distance" actually exists has been a question hotly debated in the literature. As noted by Grimes (1992), who analyzed European rural areas in the early 1990s, the debate has tended to swing from extreme pessimism to optimism concerning ICT adoption and the potential for ICT diffusion to benefit rural areas. ICTs may reduce the need for face-to-face contact, fostering a decentralization of economic activity. It has been claimed that they favor firms located in rural areas that are disadvantaged by distance. Concerning the digital divide, mobile phones seem to be the exception to the rule. A study of 28 EU (European Union) regions in early 2000 found that mobile phones were broadly dispersed, with agriculture-dominated regions (as defined by the share of agricultural employment) lagging only slightly behind other types of regions (Milievic and Gareis, 2003). This might not be yet the case in Latin America, though the data shows that the divide is smaller than for other technologies. As shown previously, rural areas seem to have especially benefitted from the diffusion of mobile phones in Latin America.

These developments have bolstered the optimism of some authors and analysts with regard to rural areas. However, the narrowing of the divide is probably not taking place for all types of ICTs. Some academics even speak of the paradox of ICTs since they believe that the adoption of these technologies may produce more centralization (Grimes, 1992). Some authors argue that ICTs actually constitute another aspect of unequal development, especially concerning the most sophisticated services used by business (e.g. Berkeley et al., 1996). The previously cited study on EU regions seems to confirm this view. While mobile phone use in everyday life was widespread in all regions, differences between agricultural regions and other areas were considerable with regard to other ICTs like broadband Internet and e-commerce (Milicevic and Gareis, 2003). The authors report that their sample of EU agricultural regions reached only half the EU average with regard to basic ICTs.

In Latin America, the divide may be growing for ICTs other than mobile phones. According to OSILAC (2008), the availability of ICTs in Latin American urban households has increased more quickly than their availability in rural households. Cultural, psychological and institutional barriers may impede the diffusion of ICTs in rural areas (Berkeley et al., 1996). Conversely, they add, the ability of global cities to attract information-based activities is self-reinforcing.

The data available from Latin American population and housing censuses confirm the existence of a urban/rural divide for all types of ICTs. However, the divide varies widely among countries and among the various technologies. Table II.1 illustrates the divide regarding household access to several different ICTs. As stated earlier, the data for rural areas probably do not accurately reflect the actual level of ICTs adoption by farms and other agricultural establishments.

As expected, in most countries the divide is quite small for access to radios. Virtually non-existent in Ecuador, El Salvador, Panama, Paraguay and Uruguay, it is quite small in other Latin American countries. By contrast, the divide for access to fixed phones is quite large as compared to the divide for most other technologies. The magnitude of the divide also varies by country. Peru displays significant disparities in access to computers and the Internet, which is very low in rural areas. Peru and the Plurinational State of Bolivia show large disparities in access to TV; again, the percentage of Peruvian rural households that have access to this technology is particularly small. Uruguay, where the urban/rural divide for access to computers is small, illustrates the effects that public policy intervention can have on technology diffusion. The Uruguayan experience shows that the relative absence or presence of public policy initiatives can significantly affect the rate of technology adoption (Hall, 2005).[6]

2. Geographic proximity and ICT diffusion in agriculture and rural areas

The epidemic theory of technology diffusion through imitation and spillovers tries to explain why geographic agglomerations are especially propitious for rapid technology diffusion. With the possible exception of those operating in agro-industrial clusters, agricultural producers and related agri-businesses are generally not located in areas with agglomeration characteristics. This would serve, according to the above view, as a limiting factor in their adoption of ICTs. Some research, however, appears to contradict this view.

6 There is very little literature on the effectiveness of policies dealing with technology adoption.

A study carried out in France suggests that geographic dispersion may in fact stimulate ICTs adoption by firms in the agro-food industry (Galliano and Roux, 2003). The study found that a major determinant of the adoption of ICTs by such companies is multi-locality, since many of them need to manage dispersed production, processing, marketing, and distribution functions. Analyzing a large sample of French companies, the authors concluded that intranet seems to be a management tool that enables agro-food firms to manage multiple locations more efficiently. Unlike other French companies, they found agro-food firms were highly prone to adopt intranet and extranet when their operations were confronted with geographic dispersion (size of the company and other variables controlled in the econometric model). In other words, the spatial determinants of ICT adoption play very different roles in agro-food firms. In addition, unlike other French companies, location of agro-food firms in rural areas did not hinder intranet adoption and even favored extranet adoption.

The spatial structure of the agro-food company is, therefore, an important factor in ICT adoption because: the company adopts ICTs mainly to take advantage of different types of externalities (Galliano and Roux, 2003). This rationale could also apply to large Latin American agro-food companies, given the geographic size of some LA countries and, in the case of certain agricultural and forestry products, the substantial physical distance between producers and markets. Analyses of extensive ICT adoption by Argentinean soy producers, Uruguayan livestock farmers and Chilean producers of wine and salmon provide empirical support for our interpretation (Moguilansky, 2005). Firm size, geographical dispersion and the need for access to international markets are all factors that can drive ICT adoption and diffusion. In a sample of Chilean agricultural enterprises, 96% of the medium and large producers had computers and the number of computers in the enterprise increased with size, complexity of tasks and level of diversification (Nagel and Martínez, 2006). These findings are in line with the results of the above-mentioned French study.

Differences between remote and accessible (core) rural areas concerning ICT awareness and use are noticeable even in developed countries (Berkeley et al., 1996). Some evidence seems to support this finding for Latin American rural areas. Data from the Mexican Population Census shows that there may be substantial differences in access to ICTs between rural localities, depending on the size of the locality. Disaggregated tables of Census indicate that 45.4% of Mexican rural localities (defined as those with less than 5,000 inhabitants)[7] had no public telephone service in 2010. However, localities without public telephone service rose to 61.3% for localities with 250-499 inhabitants and to 66.9% for the smallest localities (1-249 inhabitants). Nearly one-fifth of the Mexican rural population lived in localities of less than 500 inhabitants in 2010.

The data suggest that many rural Mexican farmers, as is the case with producers in other developing countries (Aleke et al., 2011), may need to devote time and money to access public telephone services. Again, this evidence confirms that location still matters concerning ICT adoption. In Latin American agriculture adoption can be strongly influenced by the proximity of the enterprise or farm to larger rural communities or to urban areas.

Social interaction also appears to influence technology adoption. A study of Australian rural areas found that individuals who were isolated from their peers tended to be slow adopters, or low users, of ICTs (Chung and Hossain, 2010). The authors concluded that it is important to consider the professional network characteristics of potential ICT users. This may also be the case in many Latin American rural areas.

Some studies suggest that, in developing countries, location in rural areas is not necessarily a deterrent to new technology adoption (e.g. Rivera et al., 2005). Even in remote areas, some authors claim, people are motivated to use new technologies when three conditions are in place:

- When information on input or product markets is available;
- when information on agricultural production is provided; and,
- when potential adopters participate in producers' organizations.

Empirical studies corroborate the importance of the last factor in ICT adoption by agricultural producers in developing countries. For farmers who live in these countries, participation in social networks may be a substitute for physical proximity. Often, small agribusinesses in developing countries learn about ICTs through social networks (Aleke et al., 2011). Awareness is important. For instance, a study on Malaysian agro-based entrepreneurs found that a major obstacle for ICT adoption was that the

[7] According to this source, such localities amounted to more than 24 million inhabitants. Localities with less than 50 households were excluded.

respondents did not know the benefits of the new technology (Hassan et al., 2009). Not only learning about ICTs, but actually adopting it seems to be influenced by the participation of the producer in social networks. An experiment carried out in a rural area of coastal Peru showed that producers with high social capital, as measured by their participation in professional organizations, were more interested in learning how to use smart phones than less well-organized producers (Bustamante Vento, 2011).

D. Location and ICT adoption in Latin American agriculture

One of the main trends affecting ICT adoption in Latin American agriculture is related to new international patterns of technology adoption. The literature indicates that since the 1980s different patterns of technology diffusion have emerged. While previous research assumed that technology would diffuse internationally following the product life cycle, some authors have pointed to the potential of technological "leapfrogging", i.e., the possibility that "late industrializing countries can assimilate technological innovation more quickly than earlier industrialized ones" (Antonelli, 1990). Notably, it has been claimed, telecommunication technology use is likely to expand quickly in countries with low levels of pre-existing communications infrastructure because it is easier to diffuse systemic innovation from scratch than to add to existing systems on a piecemeal basis.

The case of mobile phones is an example of technological leapfrogging (OSILAC, (2008). In Latin America, households with no access to electricity or fixed line phones are able to use mobile phones because they can be periodically recharged with car batteries. Rural households are more likely than urban households to lack electricity and landline access, a telecommunication deficit that can now be overcome through mobile telephony.

The International Telecommunication Union (ITU) reports that in developing countries the use of mobile phones has grown more quickly than fixed phone usage. Supporting theories of leapfrogging in ICT diffusion across countries (Antonelli, 1990), the evidence presented below seems to be in line with these international developments. The number of mobile phone subscribers in Latin America and the Caribbean is quite comparable to subscriber rates in OECD countries. In both cases there is more than one mobile phone per capita: in 2011 the indicator of access to mobile phones reached 106.7% and 112.5%, respectively, in LAC and OECD. In the LAC region this indicator is particularly high in Panama, Suriname, Guatemala and several Caribbean countries.

Table II.1 shows that Latin American rural households are more likely to have access to mobile phones than to fixed phones and this is also the case for Latin American urban households. Moreover, the leapfrogging effect is particularly evident in rural households. The urban/rural divide is much greater for fixed phones than mobile phones. The urban/rural mobile phone access divide is particularly small in Chile, Uruguay, El Salvador and Paraguay where it ranges from 12% in Paraguay to less than 4% in Chile. In stark contrast, the divide in all of these countries, in the case of access to fixed phones, is still substantial. The evidence suggests that rural areas of Latin America have especially benefitted from a leapfrogging effect in regard to mobile phones[8].

A spatial approach to technology diffusion, taking into consideration a disaggregation by rural and non-rural areas, is essential for studying ICT adoption in Latin American agriculture. It should be remembered that data for rural areas may overstate the scope of ICT adoption in the agricultural sector. For instance, a study of a rural British region conducted at the end of the 1990s found that ICT adopters tended to be firms which owed little to farming or forestry (Mitchell and Clark 1999).

The available evidence shows significant differences in the levels of ICT adoption between urban and rural areas in Latin America. Table II.1 displays data on the availability, in households, of different sorts of ICTs by area (urban and rural) for 15 Latin American countries. These countries display very different characteristics in terms of size and geography, a circumstance that makes comparisons especially difficult. In addition, other factors may determine the variability of ICT adoption in agriculture. Studying diffusion and adoption of ICT across countries, Pohjola (2003) finds, in a sample of 49 countries analyzed in 1993-2000, that the most important determinants of per capita PC expenditures were income, relative price of hardware and stock of human capital. It

8 Additional factors may have contributed to increased levels of ICT adoption in Latin American rural areas across countries. For instance, the small size of some Latin American countries, such as El Salvador and Uruguay, may have facilitated the construction of telecommunication networks in rural areas, as suggested by comparisons of the 15 countries included in the table.

could be expected, therefore, that Latin American rural populations with higher levels of income and education would display higher levels of PC adoption. Cross-tabulated data from the Brazilian and Chilean censuses of agriculture confirm this conclusion (CEPAL-FAO-IICA, 2011). Large agricultural establishments (100 hectares or more) in both countries tended to have better access to ICTs and levels of access increased notably when the entrepreneur was better educated.

On the other hand, it should be borne in mind that the Latin American countries selected for analysis display important differences concerning their respective agricultural product mix, agrarian structure (e.g., large farms, small farms, cooperatives) and type of agriculture (e.g., export agriculture, subsistence agriculture). All these factors may influence ICT adoption. Results of comparisons, therefore, should be viewed with some degree of caution.

Table II.1 shows that despite differences among countries, in all cases radio and TV are the ICTs most available in rural households in Latin America and that urban households have more access to mobile telephony than rural households. However, as stated, in several Latin American countries penetration of mobile telephony in rural areas is substantial and quite comparable to that of urban households.

With the exception of radios and, to some extent TVs and cellular phones, table II.1 shows a large urban/rural technology divide in every country. The availability of computers and Internet access is very limited in Latin American rural households. In almost every country, less than 5% of the rural households analyzed have access to the Internet. This limited access can be observed even in countries such as Brazil, Colombia, Peru and Panama, which display relatively high levels of access to the Internet for urban households. Rural Uruguayan (9.2%), Costa Rican (7.4%), Chilean (6.9%) and Mexican (6.3%) households are the exceptions, with modestly higher levels of Internet penetration.

Table II.1
Access to ICT in urban and rural households in selected Latin American countries, by type of technology
(percentages of households)

Country/year of survey	Computer	Internet	Cellular phone	Fixed phone	Total phones	TV	Radio
Bolivia 07[a]							
Urban	18.4	5.1	77.6	31.2	83.2	87	57
Rural	0.5	0.0	18.7	1.6	19.4	19.8	49.8
Brazil 08							
Urban	35.1	27.2	80.5	50.5	87.6	97.1	89.6
Rural	7.3	3.3	48.7	9.4	51.0	83.1	83.3
Chile 09							
Urban	45.9	32.2	89.4	51.9	95.5	n.a.	n.a.
Rural	17.2	6.9	86.0	8.4	87.2	n.a.	n.a.
Colombia 08							
Urban	28.5	16.1	87.5	55.4	92.6	93.1	n.a.
Rural	2.5	0.3	70.8	5.3	71.9	72.2	n.a.
Costa Rica 10							
Urban	46.6	25.7	75.1	72.5	90.5	96.1	44.1
Rural	23.7	7.4	58.3	53.3	77.6	91.3	35.0
Ecuador 09							
Urban	31.7	10.7	80.8	47.2	87.4	n.a.	39.5
Rural	5.8	0.6	58.1	11.3	61.6	n.a.	42.1
El Salvador 10							
Urban	15.3	6.4	81	48.5	89.6	91	47.2
Rural	1.6	0.1	73.1	13.6	76.5	67.7	50.2
Guatemala 06							
Urban	18.3	3.3	66.8	31.4	74.8	85.1	53.4
Rural	2	0.1	40.9	4.5	42.7	49.4	65.8
Honduras 07							
Urban	17.8	4.9	71.6	57.9	84.6	88.9	55.4
Rural	2.7	0.1	45.5	10.1	48.6	43.4	68.2
Mexico 07							
Urban	33.1	18.3	66.6	70.5	87.4	98.6	93.7
Rural	12.3	6.3	45	37.4	61.5	88.6	84.3
Nicaragua 06							
Urban	9.8	0.8	76.5	29.2	80.7	86	43.4
Rural	1.1	0	39.4	1.1	39.6	38.2	69.1
Panamá 07							
Urban	23.5	13.2	80.7	50	89.1	95	83
Rural	4.2	0.7	46.6	15.7	51.6	60.7	74.8
Paraguay 08							
Urban	21.8	10	90.6	32.9	93.7	92.3	87.9
Rural	4.7	0.8	78.4	5.1	78.8	73.2	79.6
Peru 09							
Urban	27.7	15.4	78.1	43.8	86.7	89.7	57.8
Rural	2.3	0.1	37	1.8	37.4	4.3	76.6
Uruguay 09							
Urban	49.3	30.5	83.3	67.5	95.5	96.1	92.8
Rural	36.1	9.2	79.0	42.9	88.3	82.6	93.7

Source: ICT Statistical Information System, OSILAC.
[a] *Data on access to computer, TV and radio refer to 2005.*

The data are in line with a FAO report which notes that in developing countries the radio is still more frequently used than the Internet for agricultural information (Rivera *et al.* 2005). An interesting new development is the combination of radio and modern ICTs in some Latin American networks that provide advice and information to producers (see box II.1).

Box II.1

Combining the Internet and radio for price information in rural areas of the Plurinational State of Bolivia

This case study shows how the wide availability of a traditional communication technology --the radio-- in rural areas can be combined with the use of new ICTs to improve information in the countryside and, hence, producers' incomes (IICD 2006).

The valleys of Vallegrande produce 70% of the horticultural products purchased by the city of Santa Cruz, a relatively prosperous area of the Plurinational State of Bolivia. The local government and an association of producers have implemented a service that informs producers about the prices of these products in Santa Cruz markets. Information is sent early each morning via the Internet from Santa Cruz to a local centre in Vallegrande, which re-transmits it, twice daily, by radio. This information enables around 60,000 small farmers located 500 km from the consumer market to better negotiate prices with intermediaries.

As a complement, five regional centres equipped with computers have been established in the area of Vallegrande. These centres provide computer training to agricultural producers who can now use databases of prices in order to study trends, compare product prices and better plan production. The centres are user financed. According to the report, at least two other Plurinational State of Bolivia projects implemented by non-governmental organizations (NGOs) use radio programmes, often in the local (quechua) language, to broadcast prices of products in final consumer markets. The report estimates that the three radio programmes reach, on a daily basis, about 75% of the peasant population in their respective areas. Another programme that combines the Internet with daily radio programmes has been implemented by local governments and producers' associations in the Ichilo region of the Plurinational State of Bolivia to provide a variety of agricultural information, including local currency/US dollar exchange rates for exporters of agricultural commodities.

Source: Prepared by authors.

The household access data need to be augmented with information on the use of ICTs since people may use such technologies even if they do not have access to them at home. They may, for instance, have access to ICTs at telecentres, schools, or friends' or relatives' homes. Conversely, in a large household only one person may actually use a computer. Table II.2 shows computer, cell phone and Internet use, and frequency of Internet use, by household, for 12 Latin American countries. The data on household access to ICTs clearly differ from those on the use of ICTs.

The statistics on use confirm that people living in rural areas in Latin America are less likely to have access to ICTs. As shown in table II.3, people living in urban areas have many more opportunities to use the Internet at home or elsewhere. Urban dwellers use the Internet more, and more frequently, than rural dwellers (see table II.2).

The places where people living in rural areas have access to the Internet may be an important consideration; for instance, access to the Internet chiefly in cyber-cafes may restrain access to quality information (Pittaluga and Senra, 2007). As shown in table II.3, the greatest level of Internet use for people who live in rural areas occurs in the workplace. There are, nevertheless, exceptions since in Paraguay and Uruguay they use it more at home and, in some rural areas of Central America, public centers seem to play the most important role. In addition, the information obtained in centers specifically created for providing agricultural data may be more useful than that personally gathered by rural dwellers at home.

Pittaluga and Senra (2007) emphasizes the importance of ICT adoption in local branches of ministries of agriculture since such organs may re-transmit information to producer associations and to NGOs involved in agricultural education in remote regions. Though rural residents do not directly access the PCs in these branches, their availability in regional bodies may be very useful to agricultural producers. Moreover, as noted by the report, the systematic collection of information is often a costly and specialized task; hence the need for platforms that can retransmit data.

Evidence from Uruguay supports the conclusion that location strongly influences the availability and use of ICTs. For example, while 50% of those who lived in Montevideo had used a PC in the last six months, this was true of only 22% of those who lived in rural locations with fewer than 5,000 inhabitants (Pittaluga and Sienra, 2007)[9]. According to these authors, people who lived in Montevideo displayed the highest rate of PC use, followed by those who lived in smaller cities and, finally, by those who lived in communities with fewer than 5,000 inhabitants. People with higher incomes tended to use PCs

9 These data, nevertheless, are not comparable to those in table 1 because they refer to usage of ICTs, which may take place in households, or elsewhere.

more. Interestingly, however, even within similar per capita income brackets there were location-based differences in PC use rates: higher in larger urban communities; lower in smaller rural communities. This evidence suggests that beyond differences in income, location decisively influences the use of PCs.

Table II.2

Use of ICTs in urban and rural areas of selected Latin American countries

(percentages of households)

Country/ year of survey	Computer	Cell phone	Internet	Freq Internet [a]	Freq Internet [b]	Freq Internet [c]	Freq Internet [d]	Freq Internet [e]
Brazil 08								
Urban	n.a.	62.0	28.0	n.a.	n.a.	n.a.	n.a.	n.a.
Rural	n.a.	32.2	4.6	n.a.	n.a.	n.a.	n.a.	n.a.
Chile 09								
Urban	35.0	74.1	31.1	n.a.	n.a.	n.a.	n.a.	n.a.
Rural	10.3	68.3	7.2	n.a.	n.a.	n.a.	n.a.	n.a.
Costa Rica 05								
Urban	n.a.	61.0	33.0	22.3	8.1	2.3	0.0	67.3
Rural	n.a.	45.0	11.6	6.8	3.2	1.3	0.0	88.7
Ecuador 09								
Urban	25.7	61.4	20.7	11.8	6.7	1.8	0.3	79.3
Rural	4.4	35.8	2.3	0.7	1	0.5	0.1	97.7
El Salvador 08								
Urban	n.a.	n.a.	8.2	3.9	3.6	0.5	n.a.	91.9
Rural	n.a.	n.a.	0.5	0.1	0.3	0.1	n.a.	99.5
Honduras 07								
Urban	18.7	52.7	13.8	5.6	5.8	1.9	0.4	86.2
Rural	2.1	32.4	1.5	0.3	0.8	0.3	0.1	98.5
Mexico 07								
Urban	36.3	n.a.	27.1	9.7	14.3	2.4	0.6	73
Rural	16.9	n.a.	11.3	3.7	6.8	0.6	0.2	88.7
Nicaragua 06								
Urban	14.5	56.7	10.9	5.6	4.3	1.1	n.a.	89.1
Rural	1.6	26.3	0.6	0.3	0.2	0	0.1	99.4
Panamá 07								
Urban	28.3	60.1	21.9	10	7.7	3.4	0.6	78.1
Rural	6.8	30.3	4.1	0.7	1.7	1.4	0.3	95.9
Paraguay 08								
Urban	n.a.	n.a.	17.2	n.a.	n.a.	n.a.	n.a.	n.a.
Rural	n.a.	n.a.	2	n.a.	n.a.	n.a.	n.a.	n.a.
Peru 09								
Urban	n.a.	n.a.	24.6	10.6	10.6	3.2	0.2	75.4
Rural	n.a.	n.a.	2.3	0.3	0.9	1	0.2	97.7
Uruguay 09								
Urban	n.a.	70.8	32.0	17.9	11.4	2.6	0.0	68.0
Rural	n.a.	64.4	8.7	3.7	4.0	1.0	0.0	91.3

Source: ICT Statistical Information System, OSILAC.

[a] Uses the Internet at least once a day

[b] Uses the Internet at least once a week but not every day

[c] Uses the Internet at least once a month but not every week

[d] Uses the Internet less than once a month

[e] N.A. or no response

Table II.3
Internet use in urban and rural areas of selected Latin American countries, by location
(percentages of users)

Country/ year of survey	Home	Work	School	Another person's home	Community	Public centers	Public access	Mobile phone	Other
Brazil 08									
Urban	58.4	31.6	16.9	19.8	5.4	34.8	37.3	n.a.	n.a.
Rural	28.9	17.7	30.7	18.4	7.3	45.1	49.3	n.a.	n.a.
Chile 09									
Urban	62.6	17.2	20.0	n.a.	1.2	21.1	22.0	n.a.	n.a.
Rural	34.2	8.6	43.2	n.a.	2.1	26.3	27.8	n.a.	n.a.
Costa Rica 08									
Urban	40.4	31.2	13.9	5.9	0.5	38.4	38.8	n.a.	n.a.
Rural	23.6	22.6	17.0	5.7	0.6	54.1	54.5	n.a.	n.a.
Ecuador 09									
Urban	35.2	22.5	30.7	7.5	n.a.	n.a.	60.9	n.a.	n.a.
Rural	8.3	8.4	45.7	7.4	n.a.	n.a.	76.1	n.a.	n.a.
El Salvador 08									
Urban	33.5	10.8	8.1	2.4	0.1	44.6	44.8	n.a.	n.a.
Rural	3.6	2.9	16.5	2.2	0.2	74.4	74.6	n.a.	n.a.
Honduras 07									
Urban	19.3	19.4	13.9	n.a.	0.3	74.4	74.5	1.0	n.a.
Rural	3.9	7.5	12.0	n.a.	0.2	91.7	91.7	0.9	n.a.
Mexico 07									
Urban	38.6	23.3	9.4	2.1	2.8	43.6	45.1	n.a.	0.3
Rural	25.9	16.4	9.3	2.6	5.1	56.4	59.8	n.a.	0.7
Nicaragua 06									
Urban	5.8	22.7	22.7	1.7	0.3	64.0	64.2	n.a.	0.2
Rural	1.7	14.2	35.5	2.0	1.0	59.2	60.2	n.a.	0.0
Panamá 07									
Urban	33.4	30.2	17.8	5.6	4.2	34.1	n.a.	n.a.	n.a.
Rural	7.5	14.9	29.5	6.7	8.2	53.9	n.a.	n.a.	n.a.
Paraguay 08									
Urban	39.1	21.9	13.4	6.1	n.a.	38.9	n.a.	n.a.	0.9
Rural	25.7	9.1	22.8	3.4	n.a.	44.4	n.a.	n.a.	0.8
Peru 09									
Urban	28.9	15.7	6.7	n.a.	n.a.	63.5	n.a.	n.a.	n.a.
Rural	1.0	3.0	6.3	n.a.	n.a.	92.4	n.a.	n.a.	n.a.
Uruguay 05									
Urban	59.4	25.8	23.4	16.7	6.1	21.0	26.1	n.a.	n.a.
Rural	33.5	10.6	41.6	13.1	15.9	24.1	37.8	n.a.	n.a.

Source: ICT Statistical Information System, OISLAC.

In addition, according to the Uruguayan report, differences in PC use between the three types of localities persist in each age bracket. However, the disparity in PC use between localities tends to grow with the age of the respondent. The smallest divide is among children and adolescents who live in Montevideo and children and adolescents who live elsewhere in Uruguay. The divide between localities grows by age bracket, especially after the 20-29 cohort. As the authors observe, younger people, even in rural areas or smaller cities, probably have access to PCs in education centers. Another probable reason for relatively high rates of ICT adoption in rural Uruguay is an ambitious government program to provide children and adolescents with simple, inexpensive computers.

Further evidence supports the conclusion that age is an important factor in ICT adoption in agriculture. For example, the study of Malaysian agro-based entrepreneurs found that those who were less than 40 years old reported fewer problems in relation to ICT adoption (Hassan et al., 2009). This also seems to be true for Latin American agricultural producers. A quantitative study found that the Chilean agricultural producers most likely to use the Internet were those less than 45 years old (income, exports and other variables controlled in the model) (CEPAL-FAO-IICA, 2011).

In the majority of Latin American countries, the most important reasons for using the Internet in rural areas is for obtaining information and for education (see table II.4). Obtaining information is the most important reason in Chile, Costa Rica, Panama, Peru and Uruguay while education ranks first in Ecuador, El Salvador, Honduras, Nicaragua and Paraguay. In Brazilian and Mexican rural areas, however, people use the Internet chiefly for communication. While these data provide general information regarding why the Internet is used in rural areas, such uses do not necessarily reflect the specific reasons for Internet use by those engaged in agricultural activities. One report finds, for instance, that Chilean agricultural producers use the Internet primarily for e-mail, e-banking and for obtaining product price information (Nagel and Martínez, 2006).

Finally, as useful as they are, it should be remembered that data on urban and rural areas provide only a rough approximation of the diffusion and use of ICTs in agriculture, as evidenced by comparisons with other sources of information focusing more specifically on agricultural producers. For instance, according to table II.1, only 7.3% of rural Brazilian households had a computer. However, the sparse data on farming units gives a different picture. As early as 1998, the Brazilian Association of Rural Marketing (ABMR) reported that 14% of Brazilian agricultural producers owned a computer. A case study for the municipality of Jaboticaba, in Sao Paulo state, found that 16.6% of agricultural producers owned a computer (Borba, 2004). In Chile, as previously noted, access to a computer is now virtually universal among large and medium-size agricultural producers (Nagel and Martínez, 2006).

Table II.4

Internet use in urban and rural areas of selected Latin American countries, by reason for use

(percentages of users)

Country/ year of survey	Communication	Education	Leisure	Banking	Purchasing	Interaction public authorities	Reading/ Downloading	Other Leisure	Information
Brazil 05									
Urban	83.8	65.7	80.9	13.5	15.8	15.5	49.1	69.1	n.a.
Rural	70.8	69.7	67.8	4.8	0.7	7.4	36.3	57.8	n.a.
Chile 06									
Urban	73.7	14.7	69.5	13.2	12.7	14.8	0.0	0.0	85.2
Rural	58.3	15.2	63.2	4.3	6.2	5.8	0.0	0.0	83.6
Costa Rica 05									
Urban	81.5	58.8	60.0	24.4	8.4	0.0	0.0	0.0	78.1
Rural	70.3	64.6	52.4	16.0	3.9	0.0	0.0	0.0	70.9
Ecuador 09									
Urban	46.7	65.8	38.3	5.8	2.6	2.2	13.5	n.a.	39.3
Rural	30.9	83.5	26.8	2.8	2.1	1.6	8.5	n.a.	28.3
El Salvador 08									
Urban	21.5	65.6	2.2	0.4	0.8	0.5	0.7	n.a.	2.5
Rural	5.0	91.2	1.4	0.0	0.6	0.0	0.4	n.a.	0.3
Honduras 07									
Urban	71.6	61.2	38.0	n.a.	4.3	n.a.	n.a.	n.a.	67.4
Rural	64.4	67.0	30.6	n.a.	2.6	n.a.	n.a.	n.a.	56.9
Mexico 07									
Urban	49.3	41.5	16.7	2.3	6.1	3.2	0.3	4.0	53.0
Rural	48.2	46.1	18.1	0.9	3.9	2.2	1.4	3.2	44.6
Nicaragua 06									
Urban	78.0	58.4	58.6	5.0	3.1	n.a.	n.a.	n.a.	60.2
Rural	67.5	73.1	55.7	2.3	0.3	n.a.	n.a.	n.a.	54.9
Panamá 07									
Urban	18.7	1.6	3.4	0.9	1.3	0.4	n.a.	n.a.	73.7
Rural	13.9	1.2	3.0	0.5	0.6	0.3	n.a.	n.a.	80.5
Paraguay 08									
Urban	51.3	50.3	16.9	n.a.	2.3	n.a.	5.6	n.a.	12.5
Rural	42.5	50.8	15.5	n.a.	1.6	n.a.	1.7	n.a.	4.3
Peru 09									
Urban	76.3	14.4	60.0	7.3	3.7	6.2	n.a.	n.a.	88.5
Rural	72.4	7.2	60.4	0.6	0.5	2.1	n.a.	n.a.	87.9
Uruguay 05									
Urban	83.2	46.8	61.8	5.9	6.9	n.a.	n.a.	n.a.	86.8
Rural	66.2	56.0	65.0	1.8	2.4	n.a.	n.a.	n.a.	87.3

Source: Authors' calculations based on data from the OISLAC ICT Statistical Information System.

Household data by region also suggest that the size of the agricultural production unit influences ICT adoption, with lower adoption rates in regions where small farms and subsistence agriculture prevail. In Mexican states such as the Distrito Federal (the Mexico City metropolitan region), Nuevo León, Sonora and Baja California 43% of households had a computer in 2010, while in states where small subsistence farms prevail, such as Chiapas, Guerrero and Oaxaca, the percentage dropped to only 14% of households[10]. There were similar differences in Internet access: 36% of households in the Distrito Federal, Nuevo León and Baja California had access to the Internet, but only 10% of those in Chiapas, Oaxaca and Tlaxcala.

E. A sector-specific rationale for ICT adoption

Do agricultural producers, related businesses and companies operating in other economic sectors differ concerning ICT adoption? Cox (2002) (cited by Aleke et al., 2011) opines that agribusinesses are no different than other firms in terms of the role ICTs play in their operations and productivity. However, the available literature suggests that the rationale for ICT adoption in agriculture may differ. As noted above, Galliano and Roux (2003) found that the percentage of French agro-food firms and non-agro-food firms using both intranet and extranet was quite similar, though their respective motives for adoption were different.

The types of adopted technology may also differ. For instance, analyzing Spanish companies, Bayo-Moriones and Lera-López (2007) found that agricultural companies had fewer intranet access points and PCs per employee than manufacturing companies and a smaller share of their workforce used computers and e-mails (size of the company and other variables controlled in their model). Agricultural companies were, however, more likely to own videoconferencing equipment. Communication over longer distances seems, therefore, important for these firms. In contrast, they found no differences in the use of websites.

The study focused on a sample of companies located in Navarre, Spain, an export region for high quality wines and horticultural products. Because of the specific attributes of this region –high-value products for export markets– they acknowledge their results cannot necessarily be applied to other regions or countries. Their analysis shows that agricultural companies are not automatically less engaged in ICT adoption. Similar

[10] Encuesta de Hogares sobre la Disponibilidad y Uso de Tecnologías de la Información (Household Survey on the Availability and Use of ICTs), INEGI (Instituto Nacional de Estadística y Geografía), Mexico DF, Mexico. Data disaggregated by federal state are available only for 2010.

situations can be found among large Latin American agro-food exporters. A logit model for Chilean agriculture shows that exporters are more willing to use the Internet (CEPAL-FAO-IICA, 2011). On the other hand, the above-mentioned studies suggest that companies engaged in agricultural activities might be interested in different sorts of technology than those operating in other industries; hence, it is important to cover a large number of different technologies in studies of ICT adoption in agriculture

The agro-food sector is a multi-actor sector and the adoption of ICT does not take place in isolation. Some of the ICTs used in agriculture are developed by the life sciences and the food processing industry. ICT adoption in other segments of the value chain may also induce ICT adoption by agricultural producers.

Not surprisingly, given the pervasive nature of these technologies, part of the R&D for ICT is performed by sectors other than the ICT sector itself. For instance, a report estimates that in the European Union around 13% of the R&D for ICT is performed by the pharmaceutical and biotechnology sectors (EU, 2010). This suggests that the life sciences, closely related to agriculture and agribusiness (Christensen et al., 1996), are likely to contribute to specialized ICT innovations. Progress in the agro-food sector, some authors claim, has resulted primarily from new combinations of sciences and technologies, and combinations of these with wider changes in materials, organization, markets and so on (Christensen et al., 1996). This is evidenced by the varied patenting activities of the largest multinational food and beverage enterprises, in fields such as agriculture, agricultural equipment, refrigeration, biotechnology and electronics (von Tunzelmann, 1998).

Most authors now recognize the importance of geographic and cultural proximity in stimulating the collaboration between producers and users of technology. Common language and physical proximity contribute to exchanges of ideas and experiences that may improve the development and performance of new technologies and their adaptation to users' needs. This question has been specifically analyzed in the context of the technological collaboration between agricultural producers and their technology providers. Research has shown that such cooperative efforts have been instrumental in improving the competitiveness of agricultural producers and related enterprises in certain small countries (Andersen and Lundvall, 1988). The evidence suggests that geographical proximity between producers of ICTs for agriculture, on the one hand, and agricultural producers, on the other, may be crucial to ensuring the adoption and diffusion of such ICTs in Latin America; hence the importance of a local ICT industry.

As stated, ICT adoption in other segments of the value chain may stimulate ICT adoption in agriculture. In the case of agribusiness and retail markets, consumer behavior and values can also play a role. For instance, the value assigned by some consumers to food traceability may stimulate ICT adoption in agriculture. Analyses published in the 1980s illustrate the role played by large retailers in the United Kingdom in the adoption of new technologies in agriculture and agribusiness (Senker, 1987; Senker, 1989). Given the expansion of the largest international retailers (Economist, 1995; Reardon et al., 2003) and of very large national retailers in countries like Brazil, this may be starting to occur in some Latin American countries.

Moreover, the use of ICTs facilitates business-to-business relationships along the value chain. Some examples are the use of e-mails, teleconferences and funds transfers. A study conducted in rural Britain concluded that local businesses used ICTs primarily because of pressures from customers and suppliers (Mitchell and Clark, 1999). Manufacturing establishments located in rural areas are likely to provide processing services for farmers and maintain close contacts with producers. The presence of cooperatives, whose activities involve both agricultural production and some degree of processing, is substantial in some Latin American regions. Moreover, some food and drink "multilatinas" are vertically integrated or enjoy close relationships with producers (ECLAC, 2005). Contract farming, quite common in some subsectors of Brazilian and Mexican agriculture (Echánove and Steffen, 2005; Oman et al., 1989), may facilitate technology transfer and promote "entrepreneurial proximity" (De Propris, 2001; UNCTAD, 2001). Manufacturing and service establishments play an important role in stimulating ICT adoption in agriculture. In the future, researchers might wish to request a disaggregation of the above-mentioned information by types of areas. In our view, ICT adoption in Latin American agriculture cannot be fully understood without taking a systemic approach to the value chain.

F. Conclusions

While the ECLAC/OSILAC initiative suggests that data collection on ICT in Latin America is likely to improve in quality and comparability, current information makes difficult to reach solid conclusions. In spite of problems in comparability and in distinguishing the rural and the agricultural, the data point to the existence of an important gap between patterns of rural and urban adoption, which is more marked than that between different types of urban setting. The hypothesis that ICTs will spontaneously bridge physical and cultural distances is thus not supported by the data available for rural Latin America.

On the other hand, international research on ICT has confirmed a tendency to technological leap-frogging which belies the life-cycle understanding of diffusion which was also seen to be operating in Latin America. The mobile phone does not depend on the prior existence of a fixed-line phone and rural adoption rates in the former case approximate more closely to urban patterns. The original combination of technologies was also in evidence as radios were linked in to on-line information systems on agricultural prices to the benefit of peasant communities. The development of Internet-capable mobile phones opens new possibilities for the diffusion of the Internet in rural Latin America.

In spite of intra-regional heterogeneity, the existence of regional differences which largely coincide with the predominance of specific farming patterns and land tenure structures makes it possible to identify greater rates of adoption among larger commercial farms. Research findings suggest, however, that this may be compensated by levels of organization. Isolation, rather than farm size would therefore seem to be more important. Indeed, the decision to adopt ICTs appears to be closely related to the social and professional environment of the adopter. Age is another important factor with the urban–rural gap being less pronounced among the young, probably as a result of school ICT adoption. Income and education would also seem to be important influences on adoption. These conclusions suggest the need for public policy initiatives, especially concerning services used by businesses.

Many of the existing data sources have information on adoption at the individual household level. The public availability of ICT is, therefore, not taken sufficiently into account. Analysis of farm-level adoption, in its turn, has had to rely more on individual case-studies with the accompanying difficulties of generalizing the results. More importantly, perhaps, the focus on farm-level adoption needs to be situated within a more systemic dynamic both in terms of location, market orientation (domestic market or exports), and types/degrees of integration into value chains. In this way, the influence of demands from export markets, the co-evolution of knowledge production systems and ICT adoption, and upstream/downstream knock-on effects can be better evaluated.

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III. Trends and potential uses of ICTs in Latin American and the Caribbean agriculture

Raul Hopkins, Mônica Rodrigues and Monica Rinaldi

A. Introduction

The aim of this chapter is to take a closer look at a number of the more important ICTs used in activities related to agriculture and to classify them according to how they affect performance in the agricultural sector. The classification system has been inspired, to some extent, by a chapter in OECD Information and Technology Outlook 2010 (OECD, 2010) about measuring and evaluating the environmental impacts of ICTs. Here, the author's classification structure and terminology have been adapted and used to categorize the ICT uses discussed, according to the nature of their impact on agriculture:

(a) *Systemic impacts* (third order effects): These uses have very important, but indirect, impacts on agricultural productivity. Most of them are generic and not unique to agriculture and affect factors like the flow of information, public policymaking and administration and risk management. We have selected two groups: ICT uses related to the flow of information and the policy environment and those related to risk management.

(b) *Enabling impacts* (second order effects): Uses in this category facilitate processing financial transactions and marketing in the agro-food chain. Again, these uses are not necessarily specific to the agricultural sector and they do not directly affect productivity, but they are improving efficiency and reducing transaction costs throughout the value chain, improving access to markets and creating new market opportunities.

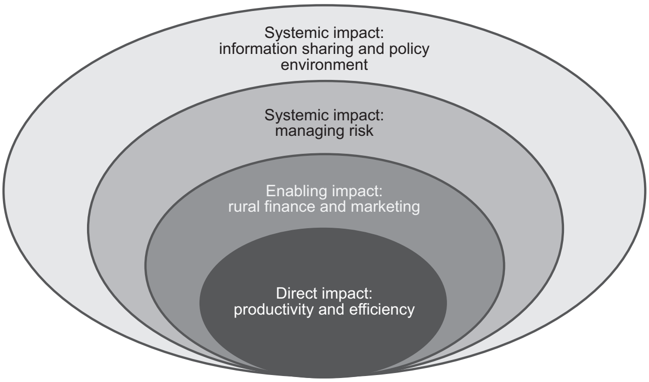
(c) *Direct impacts* (first order effects): This category encompasses ICT applications that have a primary use in agricultural production processes, with direct impacts on the sector's productivity and efficiency. These uses are linked to either the introduction of new, better inputs in agricultural production or an improved employment of usual resources.

The classification of each ICT use is also tied to the extent of its diffusion in the agricultural sector. In the first two categories (the two larger circles in figure III.1), the degree of diffusion is highest, but the direct impact on production processes is low, e.g., websites and online communities. ICT uses such as precision agriculture which have direct, significant impacts on productivity, which are much less widely diffused, fall within the smallest circle in the figure.

The classification is inherently imperfect due to the significant overlaps between ICT uses. An example is branchless banking, one of the major recent innovations which use ICTs in rural areas. The development of this strategy has been greatly facilitated by a number of online communities and there has been a significant process of sharing and learning via the Internet (a systemic impact). Nonetheless, because of the nature of its effects it has been included in the category of enabling impacts. Similarly, several elements of precision agriculture have also had an impact on risk management and agricultural sustainability. Indeed, one of the features of precision agriculture is that it simultaneously improves productivity and sustainability. However, its most substantial effect is its direct impact on productivity and efficiency.

A distinction should be made between the use of ICTs in various fields and the development of core technologies. These technologies are, among others, Geographic Information Systems (GIS), Geographic Positioning Systems (GPS), communication devices, and a variety of software and web applications. This chapter focuses on how farmers and agricultural organizations are making use of ICTs in a number of fields, but it is clear that this use is conditioned by the development of the core technologies that underlie any ICT application.

Figure III.1
A framework for examining the effects of ICTs on agriculture



Source: Prepared by authors.

Even though this chapter does not analyze the evolution of these core technologies, a table relating ICT uses in agriculture and the technologies that make them possible is presented at the introduction of each section. The analysis of different ICT uses also exhibits a similar structure along the whole chapter. First, a brief description of how the combination of ICTs is giving rise to new opportunities in agriculture is made. Second, where secondary sources of information are available, we present an assessment of the level of diffusion of the ICT uses in Latin America. Third, we make a description of relevant experiences of the ICT uses in the region. Finally, an appraisal of the main opportunities and challenges for the diffusion of ICT uses in Latin American and the Caribbean (LAC) agriculture is made.

B. Systemic impacts: Information sharing and the policy environment

ICT tools like Internet, radio, mobile phone, information sent via text messages, etc. are gaining importance as instruments to support decision making in agricultural systems in LAC. The long distances and isolation of rural areas make efficiency in communications crucial to reduce transaction costs, including the cost of travelling and the cost of obtaining information. It also makes agriculture a more environmentally sustainable activity, due to the reduction in the need for transportation.

The adoption of Internet in agricultural activities, and more specifically the use of social and global networks, enables farmers to better plan, decide and act on the agricultural processes. Several studies (Manes, 2004; Fountas et al., 2005; Blu, 2007; Leon and Best, 2008) have showed how the use of ICTs in agriculture can link users, improving farm management. ICT tools like Internet can connect users around the world who can thus be more informed and work together from different places in an easy and relatively cheap way. In the case of agriculture, this promotes a better monitoring and control, even at a distance, of different stages of the production process. The use of Internet is also gradually transforming the way farmers relate to public agencies, either as tax payers, beneficiaries of public policies and citizens.

In localities with deficient Internet connections farmers tend to use mobile phones for real time communication and to receive and send data. Nowadays mobile phones are also becoming a tool for farmers to obtain information on the efficiency of different agricultural practices. In some rural areas of developing countries, however, even the use of mobile phones can be limited by a deficient coverage, high price and low quality of the service and by limited skills and technical knowledge of farmers. Even though these barriers have been addressed and sorted by a number of policies to widen connectivity and telephony access in developing countries, the use of more traditional ICTs like radio and television is still predominant in most areas. Their potential to support the delivery of information and services should thus not be ignored.

Besides Internet and mobile phones, through which farmers and agricultural experts can share their results and estimations, the use of more advanced ICTs like GPS, sensors and cameras mounted on aircrafts and satellites also allow a better assessment of the output level of basically any crop, with important impacts on food security monitoring. Some effects of the agricultural activity on the environment –regarding, for instance, its land use, the impact on water sources and other natural resources and its carbon footprint– can also be more easily assessed by the use of advanced digital imagery technologies and geographic systems.

This section analyses the potential of ICTs to improve the sharing of information that can be useful to farmers, be this information provided by their peers, public agencies or the civil society. The use of ICTs in virtual communities, electronic government and monitoring systems for food security and environmental protection is thus considered. Table III.1 shows the related ICTs corresponding to each of these use fields. The availability and efficiency of yhese technologies condition the possibilities and the evolution of the uses analyzed.

Table III.1

ICT uses and related technologies to improve information sharing the policy environment in agriculture

ICT Use	Data origin	Data collection	Data storage/ management	Data access/ exploration	Data processing	Communication
Virtual communities	Mostly users	Internet connected computers and smart-phones	Public and private websites	Subscribed or free webpages; digital multimedia (video, audio, etc.)	Managed by administrator or moderator based on previously agreed rules	Chat, instant messaging, forums, surveys, e-mail alerts
Electronic government	Public agencies and users (individuals, civil society, businesses, employees)	Internet connected computers, tracking systems, PDAs, SMS, telephone, fax, etc.	Secured public agencies or outsourced websites	Universal, protected/ authenticated access; portals and platforms containing information and/or services (payments, certificates, extension, etc.)	Different standards for public and sensitive (personal or confidential) information regarding data integrity, encryption and authen-tication	Two-way commu-nication between public agencies and users based on online forms, e-mail, instant messaging, forums, surveys, chat, TV and radio
Environ-mental and food supply monito-ring	Public agencies, private companies and civil society	Geographic Positioning Systems (GPS), sensors, radiometers, spectro-meters, digital cameras, online forms and polls	Public and private websites powered by Geographic Information Systems (GIS)	Mostly free webpages; mapping, visualization and analysis of space-temporal variables, web-GIS, spatial data mining	Mathematical and spatial models, GIS	Online visuali-zations, e-mail and SMS alerts; forums, TV and radio

Source: Prepared by authors.

1. Virtual communities

A virtual community is a group of people that share common interests, ideas and feelings over the Internet or other collaborative networks. The term is attributed to Howard Rheingold who created one of the first major Internet communities, called "The Well". In his book, *The Virtual Community*[11], Rheingold

[11] http://www.rheingold.com/vc/book/

defines virtual communities as social aggregations that emerge from the Internet when enough people carry on public discussions long enough and with sufficient human feeling to form webs of personal relationships in cyberspace.

In agriculture, virtual communities play a key role in knowledge management, helping the process of organizing, sharing and disseminating technical information. They hold great potential for rural areas because they provide a way to overcome the geographical dispersion of rural producers and entrepreneurs. As such, virtual communities have been both an enabling tool and an output of many agricultural development projects. As showed on table III.1, virtual communities are basically constituted by user data with some administrator intervention and enabled by ICT developments like email, newsgroups, chat, message boards and instant messaging.[12]

a. Current situation in Latin America and the Caribbean

Virtual communities are fairly widespread in LAC, although their dissemination has taken place mainly in urban areas. However, over the past few years a number of agricultural online communities have been created in the region, several of which are discussed below.

The most important constraint in rural areas to taking advantage of virtual communities is insufficient Internet access. According to a study of the International Telecomunications Union (ITU), 83% of rural households in Latin America and the Caribbean have access to electricity, 38% to telephones, but only 3% to the Internet (ITU, 2008). Please refer to chapter II of this publication for a much more detailed discussion of the diffusion of these core technologies.

b. Relevant experiences

An excellent summary of best practices is GFAR-FORAGRO-IICA (2007), on which this section is partially based. In 2006/2007, FORAGRO's Technical Secretariat prepared a compilation of success stories on the use of ICTs for technological research and innovation aimed at agricultural development. [13] Four of the cases that were chosen for publication are

[12] A discussion about types of virtual communities is found in Boettcher (1999). See also the Full Circle Associates' set of resources, http://www.fullcirc.com/resources/online-community-toolkit/

[13] FORAGRO is the Forum for the Americas on Agricultural Research and Technology Development.

summarized in this section: (i) the Agricultural Information System for the Cauca Valley in Colombia (SISAV) (see box III.1); (ii) The National Voice Network, a tool for technological innovation and research at the Bolivarian Republic of Venezuela's National Agricultural Research Institute (INIA); (iii) The Electronic Potato Network (REDEPAPA); and (iv) The Virtual Network on Rural Agro-Industry (PRODARNET).[14]

Box III.1

YOAGRICULTOR (FIA-BID Project)

Improving the competitiveness of small farming companies through the use of Information and Communication Technologies (ICT)

From 2008 to 2010, the Foundation for Agricultural Innovation (FIA) of the Chilean Ministry of Agriculture together with the Inter-American Development Bank (BID), carried out the project called "Improving the competitiveness of farming small companies through the use of Information and Communication Technology (ICT)".

The overall aim of this project was to contribute to the inclusion of both micro and small rural companies into the national and international food markets, by strengthening the competitiveness of rural agriculture through ICT solutions that improve the access and use of relevant information related to the decision making process.

The project started by creating partnerships with different groups of small farming companies working with four production areas: berries, corn, wine and honey. All of them are located in two regions of Chile: O'Higgins and Maule.

The development of this project made possible the creation of four virtual communities of producers working in the mentioned fields. These virtual communities were implemented on a computer system called "YOAGRICULTOR" (Available at: http://www.yoagricultor.cl). The farmers are currently in charge of the "YOAGRICULTOR" system.

This project has been regarded by participants, professionals and advisors as an innovative and arduous work. In addition, this work has been valued and recognized because it was done using the language of the farmers and taking into account their own needs, contexts and concerns.

Finally, another outstanding element in this project was the "technical itinerary", which emerged from the "YOAGRICULTOR" system for each field. It improves the farmer's making decisions process with regards to the production, selling and productive planning stages based on "the natural cycle". In sum, the technical itinerary gives this project an added value, which allows small farmers to organize, design and guide their work based on their own experiences and knowledge.

Source: Francine L. Brossard - FIA-BID Project Director.

[14] The first two cases ("REDesastres: a contribution to the management of health disasters involving plants and animals" and "An early warning system for Asian soybean rust, Paraná State, Brazil") are discussed later in this chapter.

- Twenty agricultural institutions have come together to share their information resources on the Internet, through the electronic portal known as the Cauca Valley Agricultural Sector Information System (SISAV).[15] It allows participating institutions to publicly disseminate their knowledge through online databases. They also share geo-referential information as well as information about the people and institutions involved in the agricultural sector in the Cauca Valley region, from small farmers to international consultants and heads of institutions. SISAV promotes the use of the Internet, fostering e-commerce, disseminating knowledge about strategic issues in the region and encouraging the emergence of virtual communities.

- The National Voice Network has enabled the National Agricultural Research Institute of the Bolivarian Republic of Venezuela (INIA) to establish a voice network over its existing data transmission infrastructure by means of digital telephone switchboards that can reach the most remote rural areas via the Internet. The project is coordinated by INIA's general management with the participation of technicians at 25 Agricultural Research Centers covering 18 of the 22 states in the country. Thanks to this application of ICTs, farmers, researchers, technicians and professionals throughout the Bolivarian Republic of Venezuela interact through individual and conference calls, describing and comparing agricultural research experiences and promoting innovation and development.

- The Electronic Potato Network (REDEPAPA) hosts a virtual community centered on potato production in Ibero-America. REDEPAPA gathers and disseminates information about the potato through its website.[16] It has also created online forums and developed training materials for transferring information using ICTs. REDEPAPA uses a variety of tools: a website, an electronic newsletter, an email list, a blog, a wiki, electronic forums, a news and content syndication service (RSS) and e-mail alerts.

- Finally, the purpose of the Virtual Network on Rural Agro-Industry (PRODARNET)[17] is to establish a virtual space for the exchange and dissemination of information among producers, businesspeople

[15] http://sisav.valledelcauca.gov.co/.
[16] http://redepapa.org.
[17] www.prodarnet.org

> and technicians about issues related to rural agro-industry, which has allowed the development of a collective knowledge base. The network is based on the premise that the most valuable information comes from people's experiences. It connects those who are looking for solutions to their problems with those who can help. Created in October 1996, the network started with 20 members, using a server at the Interamerican Institute of Cooperation for Agriculture (IICA) headquarters, and relies on the Majordomo electronic mailing list program. The mailing list format is well-adapted to this purpose and has made it possible to establish a virtual community that operates within Yahoo! Groups with the following functions: (i) dissemination of general news about the performance of the rural agro-industrial sector in LAC; (ii) announcements of events (courses, seminars, meetings); (iii) responses to questions about technical and business issues; (iv) hosting a virtual showcase for marketing agro-industrial products; (v) an online forum; and (vi) a contact mechanism.

Another outstanding experience refers to the online training programme for agricultural extension workers conducted by Manuel Mejia Foundation in Colombia. Manuel Mejia Foundation is associated with the National Federation of Coffee Producers, which has been engaged in training activities for agricultural producers since 1960. Manuel Mejia Foundation, in turn, has a large background on distance learning and, more recently, online training. In 2004 the Foundation started a programme of online training for extension workers in the coffee sector, which also included researchers from CENICAFE (the National Center for Colombian Coffee Research). The programme uses *Blackboard*, the technological platform developed by SENA (the National Learning Center), to disseminate around twenty courses that comprise the core of the training programme, classified in four thematic areas (coffee technology, rural extension, economics and management). Extension workers have also access to two additional basic courses: informatics and coffee institutions. This experience has been used as a basis to develop other online training projects, some of them aimed at agricultural producers in areas like maize and gourmet coffee production, commercialization and community mediation.

c. Potential and current challenges

Virtual communities, such as those presented in this section, have enormous potential as they allow: (i) the exchange of information among member producers; (ii) the development of links and partnerships among participants; and (iii) the provision of mechanisms to facilitate learning and skills development. In addition to the cases summarized here, there are rural virtual communities in various countries in Latin America and the Caribbean. See, for instance, the list of programs and projects included in the appendix of GFAR-FORAGRO-IICA (2007), most of which are virtual communities.

The major barriers to the development of virtual communities in rural areas in Latin America are limited Internet access and insufficient digital literacy[18]. The international literature (see, for example, Thomson, 2004) cites the following as critical factors in creating such communities: (i) the role of the facilitator, which is labor intensive and requires a great deal of effort in terms of planning and contact with users; (ii) the size of the virtual community (larger virtual communities have a greater impact, but they encounter difficulties in establishing and maintaining relationships among their members); and (iii) the need to develop relevant content in order to increase and sustain membership and member involvement. The "build it and they will come" approach taken in many cases has often resulted in failure.

It has been acknowledged that in developed countries farmers massively use virtual communities for learning together about common issues. This pattern is however far from the reality of most developing countries, due to limitation in connectivity and equipment as well as constraints in skills and technical knowledge of farmers and rural areas. Developing the ability of farmers for using ICTs as a tool for collective learning is a major challenge in agricultural countries, especially if the aim is to involve older farmers. Improving their skills to use ICTs implies in some cases to start by providing formal education; however, this can also be done through the implementation of friendly tools and services especially developed to meet their needs and skills. The benefit of incorporating older farmers in the use of ICTs include the codification and eventual transference to new generations of a tacit, invaluable knowledge that otherwise might be lost.

[18] A simple correlation analysis is consistent with the enormous potential of networks in rural areas. The figures reported by ITU (2008) show that there is a positive correlation between the degree of rurality and the use of social networks (as a percentage of the families with Internet access).

2. Electronic government

E-government is the use of information and communication technologies for government operations and for providing public information and services to users, primarily through Internet applications.[19] ICT tools related to e-government include: Internet, electronic records management, software programs for public administration, government sites offering a variety of information to users, digital payment services and other online procedures and electronic forums and consultations. These tools can be classified in three groups: government-to-government (Intranet, electronic records, public administration software); government-to-users (information and payment services); and government-to-citizens (electronic forums and consultations) (Christensen and Laegreid, 2008). Bersano (2006) discusses the indicators used to measure the degree of e-government development. She distinguishes three levels: e-administration, e-policies and e-society services. The development of e-government represents a paradigm shift as summarized in table III.2.

Table III.2
E-government: a Shifting paradigm in public service delivery

	Bureaucratic paradigm	E-government paradigm
Orientation	Production and cost efficiency	User satisfaction and control, flexibility
Process organization	Functional rationality, departmentalization, vertical hierarchy of control	Horizontal hierarchy, network organization, information sharing
Management principle	Management by rule and mandate	Flexible management, interdepartmental team work with central coordination
Leadership style	Command and control	Facilitation and coordination, innovative entrepreneurship
Internal communication	Top-down, hierarchical	Multidirectional network with central coordination, direct communication
External communication	Centralized, formal, limited channels	Formal and informal direct and fast feedback, multiple channels
Mode of service delivery	Printed material, and interpersonal interaction	Electronic interactions
Principles of service delivery	Standardization, impartiality, equity	User customization, personalization

Source: Ho (2002: 437).

19 For a review of definitions and functions of e-government see Lee et al. (2008).

E-government can play a critical role in improving the efficiency and competitiveness of agriculture: reducing costs, modernizing and optimizing the provision of public services and facilitating the timely transmission of critical information to farmers and intermediaries. ICTs can also be important tools for increasing government transparency and promoting and facilitating public participation in policy design, implementation and evaluation.

a. Current use in Latin America and the Caribbean

In most government agricultural agencies in the LAC region, ICTs are increasingly being used to gather, store and disseminate information and to provide services.[20] However, the literature assessing e-government, particularly in agriculture, is rather limited.[21] The available studies on innovative practices (see, for example, United Nations, 2006) are generic in terms of sectors and make no specific reference to agriculture.

There are, however, important exceptions. Nagel (2009) examines the development of ICTs in Chilean agriculture as part of the Chilean government's digital agenda, formulated in 2003 and revised in 2004, for the period 2004-2006. Acting on this agenda, the Ministry of Agriculture established a set of strategic objectives that included: improved rural connectivity and access to infrastructure, greater support for the use of georeferencing in agriculture, promoting precision agriculture and the development of information platforms and virtual communities. The following table summarizes the progress made in implementing the ICT agenda in the agricultural sector by public agencies and institutions in Chile.

In addition, there are a number of initiatives to coordinate efforts between different agencies such as the *Mesa TIC MINAGRI*, coordinated by the FIA; *Mesa Satelital*, coordinated by CIREN; and *Mesa de Información Georeferenciada*, coordinated by ODEPA. One program, managed by the Agrarian Innovation Foundation (FIA) to coordinate and centralize digital information available through the information platform i+D+I (Research,

[20] The e-government practices in Latin America examined elsewhere in this chapter are: electronic tax payment (Argentina, Chile, Peru and Uruguay), government websites (Argentina, Colombia, Peru); customs systems (the Plurinational State of Bolivia); procurement systems (Brazil, Chile, Uruguay); citizen assistance service centres and time-saver centres (Brazil) (United Nations 2006: 305-321). See also IACD (2003), which makes reference to a similar list of innovative practices in Chile, Brazil and Mexico.

[21] This is not the case in other regions where there are several studies that examine the information and services provided by government agricultural websites, such as Lee et al (2008) which compares the government agricultural websites in China, Korea, Taiwan and USA. Ntaliani et al. (2010) proposes a framework for providing online services.

Development and Innovation), is aimed at improving public access to agricultural information dispersed among different sources, facilitating decision making and contributing to capacity building on digital issues.

Table III.3

Online services provided by government agricultural agencies in Chile

Services provided	Number of institutions[a]
Information on government activities, services offered and news	10
Electronic publications including thematic reports	6
Statistical information and maps	3
Agricultural prices and related information	3
Videos on specific topics (including training and best practices)	5
Information on tenders and bids	6

Source: Prepared by authors on the basis of Nagel (2009: 23-44) and a review of the websites of the ten government agencies working in areas relevant to the agricultural sector.

[a] *The institutions are: ODEPA (Oficina de Estudios y Políticas Agrarias), INDAP (Instituto de Desarrollo Agropecuario), SAG (Servicio Agrícola y Ganadero), CIREN (Centro de Información de Recursos Naturales), FIA (Fundación para la Innovación Agraria), INIA (Instituto de Investigaciones Agropecuarias), CNR (Comisión Nacional de Riego), CONAF (Corporación Nacional Forestal) and INFOR (Instituto Forestal).*

Most e-government initiatives in the region are related to the delivery of online services to citizens, from the display of news, statistics and information on public policies, including the monitoring and impact assessment of public programmes to, in some cases, the accomplishment of procedures. The webpage of the Ministry of Agriculture and Rural Development of Colombia[22] is an example of these initiatives.

Additionally, there are several projects in the region to improve the quality of services offered by government agency websites, including ministries of agriculture.

- One such project is Standardization and Updating of the Websites of Salvadoran Government Institutions. Its specific goals are to improve the quality of government websites, in conformance with e-government best practices and the Salvadoran government's international commitments to implementing e-government, and to standardize government websites, applying a uniform web policy to

22 www.minagricultura.gov.co.

all government agencies. The project includes the implementation of 61 international standards and a common navigation system and the regulation of technological aspects of web 2.0 practices, which are of particular importance for the organization of forums, the development of social networks, blogs and so on. Box III.2 below summarizes the findings in ECLAC (2011) pertaining to the implementation of e-government in LAC. A similar initiative is underway in Ecuador.

Box III.2
The implementation of e-government in agriculture in LAC

Based on the findings of an ECLAC study on the level of implementation of e-government (EG) in the region's ministries of agriculture, LAC can be divided into three groups:

(1) Countries like Brazil, Chile, Colombia, and Mexico, which have made slightly more progress with ICTs. They have established procedures for implementing e-government and the respective ministries are working hard to incorporate them, although they are not yet fully implemented.

(2) Countries that have enacted e-government legislation but are still developing the procedures or general agreements for implementation, such as Costa Rica, El Salvador, Paraguay, Peru and Uruguay. Although the ministries of agriculture in these countries are gradually adopting the procedures or agreements that have been approved, there are processes not yet in place due to factors beyond the control of the ministries. For example, in most cases the units in charge of administering and implementing EG procedures do not have decision-making powers or the technical and economic resources required.

(3) The other countries in the region have not yet established the mechanisms for implementing e-government and have no agency in charge of administering and implementing EG procedures. Although most of the ministries have ICT equipment and applications, it is very basic (word processors, spreadsheets, e-mail, and so on) and has little impact on management processes.

Source: *ECLAC (2010).*

- In Mexico the Information System for the Rural Sector (SISER) and the Single Information Registry System (SURI), both developed by the Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), are examples of the efforts some countries in the region are making to bring e-government practices to the administration of public programmes for the rural areas. These systems operate at all administrative levels, from national to municipal, and display online information on the requirements and procedures to accede to the public programmes managed by SAGARPA. They also keep the records of producers that have applied to these programmes, facilitating future applications and the monitoring of the resources invested, and deliver impact assessment studies of some programmes.

- Regarding the design of public policies, one example is the on-line public consultation system used by the Ministry of Agriculture and Livestock (MAG) of Costa Rica to design the Public Plan for the Agrifood Sector and Rural Development 2010-2021 (MAG, 2010).

b. Potential and current challenges

The literature on ICTs use is traditionally focused on the private sector. However, this has changed in the last ten years with the increasing recognition of the importance of ICTs in the public sector and the use of e-business models as a means to improve the quality and responsiveness of services provided to citizens (Ndou, 2004). The adoption of e-government technologies in LAC could significantly improve government efficiency, responsiveness and access to public services.

ECLAC (2010) assessed the development of e-government in LAC, particularly in the following areas: online services, public procurement, tax administration and electronic payments. The report also highlighted a number of challenges faced in providing public services using ICTs. To address them, the report concluded that progress must be made in the following areas:

- Training government personnel and end-users in the use of online applications and tools;
- Increasing the amount of information available online and the number of interactive applications for public procurement and other government services;
- Promoting the mobile broadband availability of electronic administrative transactions;
- Ensuring that all municipalities have a broadband connection and provide community content;
- Encouraging public administration coordination and interoperability based on open standards.

These challenges are even greater in the agricultural sector due to: (i) insufficient Internet coverage in rural areas; (ii) low levels of education in general and particularly in information technology; and (iii) insufficient equipment and software in government agencies, particularly outside capital cities. In addition, attitudes and practices prevailing in public agencies can be obstructive. As noted by Basu (2004), "E-governance is more than just a government website on the Internet. The strategic objective of e-governance is to support and simplify governance for all parties; government, citizens and businesses."

3. Environmental and food supply monitoring

Table III.1 summarizes the main ICT tools related to environmental and food security monitoring. These include:

- Remote sensing infrastructure: monitoring agricultural and water resources by using high-resolution radiometers and moderate-resolution imaging spectrometers generally placed aboard aircraft and satellites.
- Data analysis and communication devices: PCs, personal digital assistants (PDAs), servers, mainframes, network databases and software are used for environmental monitoring and food security analysis, including information gathering, modeling and mapping. GIS can help to establish cross-sectoral communication by providing tools for storing and analyzing statistical data and integrating databases into the same formats and map projections.
- Communication infrastructure: information can be distributed via the Internet and other communication channels to farmers, consumers and citizens and made available on web portals and interactive maps (ITU, 2009).

Georeferentiation is an essential tool in remote sensing and geographic analysis. It can be defined as the process of assigning a geographic location (latitude and longitude) to a geographic feature. A geographic information system (GIS) allows the display of information on a map. Modern GIS technologies use a variety of digitizing techniques to store information. Hard-copy maps or surveys are transferred into a digital medium through the use of a computer-aided design (CAD) program with geo-referencing capabilities. Satellite and aerial images are now the main source of geographic data.

This visual information improves the monitoring of the agricultural process and its effects on the environment, the landscape and the populations of plants and animals. Georeferentiation is also frequently used as a support tool for decision-making and can be found as a core or enabling technology in many ICT uses in agriculture, like precision agriculture and management systems.

a. Current use in Latin America and the Caribbean

Government agencies and NGOs in the region use GIS to predict droughts, monitor water resources, visualize remote-sensing information, model data from multiple sources, evaluate economic and environmental impacts, share data and maps between agencies, comply with planning and reporting regulations and educate and advise communities via online services (ESRI, 2008). ICTs are increasingly used by environmental ministries and agencies, NGOs and the public to promote environmental management and protection.[23]

Examples of government initiatives include those of the Ministries of the Environment and similar institutions in Brazil,[24] Costa Rica[25] in and Trinidad and Tobago.[26] Regarding food security monitoring, several countries in the region are taking advantage of the global systems already in place (see table III.4).

Table III.4
Food monitoring and early warning systems in Latin America and around the world

Initials	Name	Website
GIEWS	FAO Global Information and Early Warning System	www.fao.org/giews
FEWS NET	USAID Famine Early Warning System	www.fews.net
GMFS	Global Monitoring for Food security	www.gmfs.info
VAM	World Food Programme Vulnerability Analysis and Mapping	one.wfp.org/operations/vam/about_vam/what_vam.html
MARS FOOD	Monitoring Agriculture with Remote Sensing (EC/JRC)	www.marsop.info/marsop3
EARS	Environmental Analysis and Remote Sensing	www.ears.nl
AP3A	Alerte Précoce et Prévision des Productions Agricoles (CILSS/Agrhymet – Sahel, only in some African countries)	www.case.ibimet.cnr.it/ap3a
SADC	Regional South African Early Warning System for Food Security	www.sadc.int/fanr/aims/index.php

Source: GMFS, http://www.gmfs.info.

23 A list of environmental ministries and other public sector institutions in LAC can be found at: http://www.revistafuturos.info/ciberoteca/ministerios/ministerios.htm.
24 http://www.mma.gov.br/sitio/.
25 http://www.minae.go.cr/.
26 http://www.mphe.gov.tt/.

b. Relevant cases

ICTs can be used to improve the measurement of the stock of biodiversity, increase public awareness and promote the protection of biodiversity. They can also further voluntary data collection efforts through the development of collaborative systems that incorporate tools to facilitate data collection, access and validation (Gouveia et al, 2004).

The *Fire Information for Resource Management System* (FIRMS) integrates remote sensing and GIS technologies to deliver fire location and burned-area information to natural resource managers and other stakeholders around the world. FIRMS is funded by NASA and builds on Webfire Mapper, a collaboration between the University of Maryland and NASA, which provides near real-time information on active fires worldwide, detected by the MODIS rapid response system. The Webfire Mapper integrates satellite data with GIS technologies for active fire information and makes it available to the public through the website and email alerts. Local and regional fire monitoring systems are available for Canada, South America, Mexico and South Africa (Grasso, 2009).

An interactive mapping service based on Google maps and imagery from INPE, the Brazilian Space Research Institute, has been available since September 2008. Individuals can contribute with information from the ground, and receive reports on forest fires and illegal logging, making it one of the most used websites in Brazil.[27] The information received has led to a number of legal initiatives and parliamentary enquiries.

Box III.3

CONABIO: Using ICTs to promote a better understanding of biological diversity in Mexico

The National Commission for Knowledge and Use of Biodiversity (CONABIO) is an inter-ministerial commission, which was formed in 1992. Nine ministries participate: Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), Social Development (SEDESOL), Economy (SE), Public Education (SEP), Energy (Sener), Finance and Public Credit (SHCP), Foreign Affairs (SRE), Health (SSA) and Tourism. The Technical Secretary is held by the Minister of Environment and Natural Resources (SEMARNAT).

CONABIO's mission is to promote, coordinate, support and carry out activities aimed at increasing awareness of and protecting biodiversity. CONABIO sponsors basic research

[27] see www.inpe.br/queimadas/.

that generates and compiles information about biodiversity and acts as a publicly accessible source of information. CONABIO is a bridge between academia, government and the general public that promotes the conservation and management of biodiversity and is a catalyst for biodiversity protection through local action and initiatives.

CONABIO implemented and operates the *National Information System on Biodiversity* (SNIB), provides data, information and advice to various users and participates in global biodiversity information networks in compliance with Mexico's international commitments on biodiversity. It also supports the conservation and sustainability of biodiversity through a variety of activities in which ICTs play a critical role, providing interactive platforms for its rich and extensive database of environmental resources, scientific collections, climatic mapping and learning resources.

Source: CONABIO. For further information go to http://www.conabio.gob.mx/

In Colombia, *Acciones Ambientales S.A.* specializes in developing software applications for environmental monitoring and control. Specific software products developed include SIGAM (for integrated environmental management); SERCA (for environmental control); RESPEL (for hazardous waste); and software for environmental education. The company's goal is to reduce the consumption of non-renewable natural resources and encourage the adoption of environmental best practices.

In Mexico the National Commission for Knowledge and Use of Biodiversity (CONABIO) has developed the *National Information System on Biodiversity* (SNIB) to provide data, information and consultancy services and to promote a national information network on biodiversity. SNIB is critically important to Mexico, which is second in the world in terms of ecosystem types and fourth in species richness. SNIB activities include (see box III.4): (i) gathering data from national and international biological collections; (ii) maintaining an inventory of taxonomic activity; (iii) monitoring ecosystems through remote sensing techniques; and (iv) administering a network of national and foreign experts.

REDesastres is a virtual community created in Cuba in 2006 to provide real-time information and alerts on weather and biodiversity conditions. It also provides forums and training for experts and professionals from areas including agriculture, public health, science and the environment. This network has been extended to the Bolivarian Republic of Venezuela and operates through the website,[28] where members can register and participate.

[28] http://redesastre.inia.gob.ve/.

Box III.4
Studying the impacts of climate change on agriculture with a web-gis environment

Within the Envirochange Project-Italy (2009) a new WEB-GIS environment (ENVIRO) was developed to study the impacts of climate change on agriculture at regional level. The project focuses on global change and sustainable management of agriculture in highly developed environment. It aims at assessing the short-term biological, environmental and economic impact of climate change on agriculture at the regional level (Trentino), particularly on quality and pest management that are more likely to be influenced by climate change also in short term.

ENVIRO is a modular platform. Modules are Open Source, follow international Open Geospatial Consortium (OGC) standards and are implemented as follow: enviDB is the database for spatial temporal data, enviGRID allows users to navigate through data and model in space and time, enviMapper is the web interface for decision makers, a state of the art client to map vulnerability to climate change at different aggregation scales in time and space, finally enviModel is the web interface for researchers that provides a platform for processing and sharing environmental risk models using web geoprocessing technologies following OGC standards.

Source: Prepared by the authors.

Regarding food security, ICTs can be used to estimate yields and production levels, to forecast food shortages and to disseminate information on stock and trade, allowing governments to act ahead implementing policies to avoid or minimize food supply crisis. In terms of experiences, the *Famine Early Warning System Network* (FEWS NET)[29], founded in 1985 by the United States Agency for International Development (USAID), is a 25-country collaborative effort to provide early information on food security issues. It analyzes market prices, plant diseases and weather data to predict food insecurity probabilities and issue alerts. One of the tools used by FEWS NET is a software application called "Population Explorer"[30], which shows the population in any part of the world by simply indicating the area of interest on its map. The software allows FEWS NET to estimate the number of people vulnerable to potential food shortages. Other food security monitoring systems are the ones presented in table III.4.

[29] http://www.fews.net.
[30] www.populationexplorer.com.

c. Potential and current challenges

Information and communication technologies facilitate data collection, validation, access, research and communication. They make it possible to create platforms that support public participation in environmental and food security monitoring efforts because they promote collaboration among stakeholders and allow the inclusion of volunteer-collected data. However, it is important to evaluate the performance of ICT-based tools and methodologies to promote citizen participation. In the same vein, easy-to-use tools need to be developed to support public participation.

Gouveia et al. (2004) state that developments in mobile telephony and interactive TV are promising for promoting environmental and food security collaborative monitoring. They stress that designing a Environmental Collaborative Monitoring System (ECMS) should consider three platforms to collect, access, explore and communicate environmental data (personal computers, mobile phones and interactive TV), as well as accommodating different platforms for data input and access.

C. Systemic impacts: managing risk in agriculture

Agriculture is extremely vulnerable to adverse weather conditions and agro-meteorological risk, not to mention the effects of price volatility on farmers' income. Uncertainty in agriculture is mostly linked to weather and market conditions (price, demand and stock levels, for instance). One way of reducing this uncertainty is improving knowledge and forecasts on weather, production, demand and prices at the local level. Among the several objectives of risk management in agriculture one of the most important ones is to be aware of the occurrence of potentially harmful weather conditions such as frosts, hailstorms, floods, etc. Another objective that has been gaining importance in the last years is to increase the knowledge on agricultural markets behavior.

A third important source of risk in agricultural value chains refers to the quality and safety of products delivered to manufacturers and final consumers. When these requirements are not accomplished in one segment, the whole value chain can be affected by consumers' lawsuits and boycotts, resulting in important losses to producers, manufacturers and retailers.

Modern ICTs have both improved weather modeling and forecasting capabilities and enabled much better real-time access to critical weather, market and value chain information, even in remote locations. This section analyses the potential of ICTs to help farmers manage agriculture-related weather, market and human health risks. It considers the following uses of ICTs: in weather forecasts and early warning systems, in marketing information and in traceability systems. Table III.5 below displays the ICT uses considered in this section and their corresponding core or enabling technologies.

Table III.5

ICT uses and related technologies to improve risk management in agriculture

ICT Uses	Data origin	Data collection	Data storage/ management	Data access/ exploration	Data processing	Communication
Weather forecasting and Early warning systems	Public agencies, private companies, NGOs, individuals	Weather stations, satellites, aircrafts and ships equipped with digital sensors, radars and cameras	Public and private websites	Mostly free webpages; visualization and analysis of space-temporal variables	Mathematical and analogue models	Online visualizations, e-mail and SMS alerts; TV and radio, phone calls
Marketing information systems	Public agencies, private companies, NGOs	Internet, intranet and extranet connected computers	Private websites, intranets and extranets powered by dedicated software	Authenticated access to marketing information and tools to plan and manage the marketing aspects of the business	Dedicated software such as Enterprise Resource Management (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM)	Two-way communication between the enterprise staff, partners along the value chain and customers based on e-mail, instant messaging, chat, surveys, phone calls
Traceability systems	Public agencies and private companies	Tracking systems include digital records, barcodes, Radio-frequency identification (RFI) tags and readers; Internet, intranet and extranet connected computers	Public and private websites, intranets and extranets	Authenticated access to, mapping and visualization of product information; Electronic Product Code (EPC) network	Dedicated software, Geographic Information Systems (GIS)	Two-way communication between public agencies, private companies, their partners along the value chain and customers based on online forms, e-mail, instant messaging, chat, phone calls

Source: Prepared by authors.

1. Weather forecasting and early warning systems

Agriculture is a climate and weather dependent activity and uncertainty in the sector is in many cases linked to atmospheric unpredictable conditions. ICTs can be used to reduce this source of random variability by increasing the awareness of the occurrence of potentially harmful weather conditions and natural disasters such as frosts, hailstorms, floods, etc. ICTs can also be used to improve the knowledge on local climate and the path and effects of climate change on crops and animals.

ICTs can help reduce uncertainty in weather forecasting due to a progressively faster increase in the capacity of computers and other tools to manage and model large datasets. With the currently available technology some farmers can have access to a more accurate and timely (local) weather information than the one provided by meteorological public services. While weather alarms or alerts can reach virtually any farmer via radio, a service of local weather information sent via short message services (SMS) can also be hired in many areas. Individual weather stations are more sophisticated options. Local information provided by private weather stations can be gathered and modeled to make advices to be delivered to farmers in real time, via Internet or mobile phones.

The use of mobile phones to communicate information concerning weather conditions to producers has been described as one of the main outputs of several projects around the world. Not only the use of inputs like water and agrochemicals can be optimized by the employment of opportune and accurate weather information; human and material losses can also be avoided by taking preventive actions ahead of the occurrence of extreme weather conditions.

ICTs have improved the ability to predict natural-disaster related events and quickly distribute information to those potentially affected.[31] ITU is the leading United Nations agency for information and communication technologies and operates the Global Observing System for weather monitoring and early warning (ITU, 2010). It includes: (i) weather satellites that track the progress of hurricanes and typhoons; (ii) weather radars that

[31] This section deals mainly with the management and dissemination of information related to extreme weather conditions and natural disasters through early warning systems (EWS). The topics examined are those usually included in the EWS literature (see for example Grasso, 2009). The analysis of the warning systems related to pests and weeds can be found in the last section of this chapter.

track the progress of tornadoes, thunderstorms, and the effluent from volcanoes and major forest fires; (iii) radio-based meteorological systems that collect and process weather data; (iv) satellite systems that gather environmental information; (v) terrestrial and satellite communication systems that issue early warnings for natural disasters and disseminate information on disaster relief operations. Thanks to these and other technologies, it is now possible to better predict and prepare for natural-disasters related events or harmful weather conditions. This is especially important in the developing world where the deadliest events causing natural disasters occur —earthquakes, floods, cyclones, droughts— and which is home to approximately 85% of the world's population.

a. Current use in Latin America and the Caribbean

National Agricultural Research Institutes (INIAs) in LAC countries like Argentina, Chile, Peru, Brazil and Uruguay have been developing decision-support, weather-based tools with an interdisciplinary approach, implemented at regional or national levels.

In Argentina the Association of Agricultural Engineers of the Cordoba Province (AIASEC) provides real time services to advice producers when the conditions are not ideal to perform some agricultural procedures (e.g. when the wind speed is not adequate for spraying or when the weather is propitious to the occurrence of diseases). In Peru a PAHO project use mobile phones to deliver agricultural information in real time, using Datadyne's services to interchange data and inform about the weather and the best time for agricultural practices. At the international level, the International Research Institute for Climate and Society (IRI) at Columbia University works on the development and implementation of strategies to manage climate related risks and opportunities in Latin America, in sectors such as agriculture, food security, water resources and health (Fiondella, 2007).

Each LAC country has to deal with specific natural-disasters related events, but there is a greater risk for Central America and the Caribbean due to their tropical position and exposure to seasonal tropical storms and hurricanes. The United Nations, through GIEWS and USAID (FEWS NET), among others, continuously monitors weather patterns via satellite images and can identify populations at risk and send warnings to the respective countries. Table III.6 shows some global initiatives to monitor climate and weather conditions and to help act ahead of natural disasters.

Table III.6
Early warning systems for extreme weather conditions in Latin America and around the world

Initials	Name	Website
CIIFEN	International Research Centre on “El Niño”	www.ciifen-int.org
CEPREDENAC	Centro de Coordinación para la Prevención de los Desastres Naturales en América Central	www.sica.int/cepredenac
SATCA	Sistema de Alerta Temprana para Centroamérica	www.satcaweb.org
DMC	Drought Monitoring Centres (SADC/IGAD)	http://www.sadc.int/dmc/

Source: GMFS, http://www.gmfs.info.

b. Relevant cases

Floods are the deadliest natural hazards and are currently increasing in frequency; however, as noted by Grasso (2009), there is a lack of flood monitoring and warning systems, especially in areas of the less developed world prone to serious flooding - Bangladesh, Brazil, China, India, Nepal, and West Africa. In addition, on a global scale, flood-monitoring systems are more developed than flood early warning systems. Existing technologies for flood monitoring must be improved with a view to increasing prediction capabilities, flood warning lead times and incorporating effective EWS.

In Central America, El Salvador, Guatemala, Honduras and Nicaragua use telemetric EWS[32] for a number of rivers prone to flooding. The Bolivarian Republic of Venezuela, Colombia and some other South American countries also use them to detect the potential for flooding. Colombia, Ecuador, Mexico, Montserrat and Nicaragua lead efforts in EWS for volcanoes. Cuba, the Dominican Republic Jamaica, Mexico, the Netherlands Antilles, Panama, and several South American countries operate weather radars as part of their EWS for floods. Ecuador uses an EWS to send text messages to coastal inhabitants, alerting them to potential extreme weather events.

Regarding climate change monitoring, it is now possible to model the spatial distribution of varieties using an open source framework and other ICT

[32] Telemetric warning systems are remote monitoring systems that send signals (via radio, cellular or telephone line) when certain event occurs.

tools to simulate IPCC (HADCM3) climate change scenarios (Golicher and Cayuela, 2007). Only ten years ago the capacity of the best available computer was not able to process the necessary information to obtain those forecasts. In Brazil, thanks to this recently available computer capacity, the yield of irrigated rice in climate change scenarios could be simulated (Walter et al, 2010). Other projects around the world are also using GIS and other ICTs to assess climate change impacts on agriculture and to prescribe adaptation and mitigation practices for farmers (see box III.4).

c. Potential and current challenges

One of the most relevant roles for ICTs in early warning systems is to reach the greatest number of people as soon as there is news of a possible disaster. Newer technologies —the Internet and mobile communication devices— can greatly improve the effectiveness of EWS. Coupled with their role in monitoring and predicting potential catastrophic events, they hold out great hope for reducing the toll in human life and property damage that results from natural disasters.

While modern ICTs have greatly improved our ability to monitor, predict and warn, much more needs to be done. The challenge is to transform climate and weather data into information that results in appropriate agronomic and preventive recommendations that can properly and timely reach farmers. Further work is thus needed at least in the following areas (Grasso, 2009):

(i) Filling existing gaps: Prediction capabilities for a number of natural hazards like landslides, droughts and forest fires need to be improved. Flood prediction systems require improvement. There are ongoing efforts to develop better systems in all of these areas.

(ii) Capacity building: Basic early warning infrastructures and capacities are needed in the parts of the developing world most affected by natural disasters. Key objectives are: (a) development of research, monitoring and assessment capacities, including training in assessment and early warning systems; (b) access to scientific information, including information on state-of-the-art technologies; (c) education and awareness-raising, including networking among universities with programs of excellence in the field of ICTs and emergency management; (d) training courses for

local decision makers; and (e) mechanisms for bridging the gap between emergency relief and long-term development.

(iii) Bridging the gaps between science and decision-making and strengthening coordination and communication links**:** The application of scientific and technological advances in modeling, monitoring and predicting capabilities could significantly improve early warning systems. A major challenge is to ensure that early warnings result in prompt responses. ICTs can play a key role by helping to ensure that information is effectively disseminated in forms accessible to end-users.

The cost of equipment for early warning systems in LA is one of the remaining challenges in the region. Although many countries possess at least some kinds of low-tech early warning systems, international and regional cooperation is vital for minimizing the consequences of natural disasters. In some cases, there is a lack of trained personnel to manage and maintain the equipment as well as a lack of scientific understanding about the dynamics of natural phenomena and their consequences.

2. Market information systems

Market risk in agriculture is linked to changes in prices of outputs and inputs after farmers have engaged in production. Agricultural markets, especially in the case of main commodities, are globally integrated. Farmers producing in one region can thus be affected by events occurring in other remote, not connected regions via international prices. Due to the complexity of agricultural markets and their high volatility, as well as the length of agricultural production cycles, farmers' actual returns can be very different from returns expected at the moment they invested in production.

Beyond international quotations, prices paid to farmers are also affected by a combination of local conditions such as distance to markets, transport infrastructure, market concentration and access to relevant information on prices, supply and demand, among others. Access to reliable, timely information about crop prices and trends can help farmers —especially small scale rural farmers— to decide where and when to sell their products. It also puts them in a better position to negotiate with intermediaries, reducing information asymmetries.

ICTs can help producers receive the information they need in a number of ways. Government agencies, farmers' organizations and NGOs often set up online national and regional price information systems that include current market prices. The systems can expand their reach by sending market information via SMS to cell phones or through local radio and TV broadcasts to reach communities that are more isolated.

a. Current use in Latin America and the Caribbean

Most governments in the region have implemented policies and programmes to address agricultural market risk and asymmetries, many of them based on ICTs. These initiatives are usually Agricultural Market Information Systems (AMIS) intended to increase efficiency and transparency in agricultural markets and to promote the competitiveness of agro-businesses by providing information on harvest estimates, market prices, volumes traded in agricultural markets and market trends. Beyond government initiatives, private systems can also be found in the region, usually supported by farmers' and traders' organizations. They can be either public goods or subscription services.

b. Relevant cases

In the Plurinational State of Bolivia, three NGOs[33] located in different parts of the country collect prices from the main regional markets on a daily basis and transmit them via the Internet to rural information centers managed by farmer associations. The information is then disseminated through twice-daily radio broadcasts in the local language. It is estimated that the broadcasts can reach about 75% of the farmers in the region. Some programmes, in addition to broadcasting prices and other useful information, offer seminars on how to interpret prices and exchange rates.

In Chile, where cell phone use has increased dramatically, price information systems are taking advantage of existing technologies to reach small farmers. One example is the information system developed by ODEPA (*Oficina de Estudios y Políticas Agrícolas*), from the Agriculture Ministry, which uses Short Message Service to deliver price information to farmers.

[33] Fundación Acción Cultural Loyola (ACLO), Instituto de Capacitación del Oriente (ICO) and Centro de Promoción Agropecuaria Campesina (CEPAC).

Another example is *Agroportal*,[34] an ODEPA website that stores price information from the main produce markets in Santiago. Similar initiatives to send price information to farmers have been developed in Argentina, Costa Rica, Ecuador and Peru.

In the Caribbean, the Jamaica Agriculture Market Information System (JAMIS)[35] was developed by the Ministry of Agriculture and Fisheries, with support from the USAID, CDC Development Solutions and App Venture, to collect and disseminate agricultural commodity prices in local and regional markets on a weekly basis. The information is collected at farms through handheld devices and uploaded to a national database that can be accessed through a website.

An important collective effort to facilitate the exchange of agricultural market information among LA governments is the Market Information Organization of the Americas – MIOA (see box III.5).

Box III.5

The Market Information Organization of the Americas (MIOA)

MIOA is a cooperative network comprised of government agencies (or those designated by them) whose principal objective is collecting, processing, analysing and disseminating agricultural market information. With 28 member countries, its purpose is to promote market transparency through the timely, systematic exchange of information. Goals of the network include:

- Creating mechanisms that facilitate the exchange of agricultural market information among the member countries
- Facilitating the exchange of technical expertise and identifying training opportunities to enhance member countries' market information systems
- Working toward the harmonization of the methodology, technology and terminology used in gathering market data
- Promoting the concept that timely and reliable market information contributes to the efficient marketing of agricultural products and helps to identify market opportunities

Source: MIOA (http://www.mioa.org/).

34 www.agroportal.cl

35 http://www.ja-mis.com/CompanionSite/home.aspx

c. Potential and current challenges

Mobile phones are a fast and effective way to provide up-to-date information to decision makers. As technology improves and new applications are developed, systems are evolving and offering a broader range of services, reducing transaction costs and allowing farmers to make better market decisions. There are a number of experimental efforts aimed at improving access to agricultural information systems using mobile telephony. Descriptions of these systems can be found in electronic forums on the subject (see box III.6 below).

Market information services require a large initial investment and entail high operating costs in order to keep their data accurate and up-to-date. Often, organizations providing these services receive support from donors to share the costs and risks involved. Given these circumstances, an important challenge is to develop viable business models to ensure that the provision of services becomes sustainable once outside support is gone (USAID, 2010a).

Box III.6

The use of mobile telephony in agricultural market systems

In recent years, there have been significant innovations in the use of cell phones for the collection and dissemination of agricultural information. Several electronic seminars discuss this and one excellent source is e-agriculture, a global community facilitating dialogue and sharing resources on the use of ICTs for sustainable agriculture and rural development.[a]

The following electronic forums organized by IICA Uruguay and the International Development Research Centre (IDRC) also provide valuable information about recent innovations in mobile telephony and agricultural market information systems in the region: "*Tecnología Móvil en el Sector Rural y Agroalimentario: Experiencias Internacionales y Oportunidades para Uruguay*" (6-19 July 2010); y "*La telefonía movil y la democratización en los Mercados Agrícolas*" 13-21 October 2011).

Examples of systems currently in use include:
DatAgro's system in Chile, supporting agricultural production through SMS;[b]
In Argentina, the cell phone alert system, *Sistemas de Alerta a teléfonos celulares* (INTA)[c], and *Agromensajes* in Peru.[d]
A summary of the results of the most recent electronic forum on the subject in LAC can be found at Fossatti (2011).

Source: Prepared by authors.
[a] *See http://www.e-agriculture.org/mobile-telephony-rural-areas.*
[b] *http://www.datadyne.org/.*
[c] *http://www.youtube.com/watch?v=dne3HU8y-Gk.*
d *http://www.minag.gob.pe/.*

3. Traceability systems

The international community is increasingly demanding greater care to ensure food quality and safety, especially since the mad cow disease outbreak in 2005. The demand for new controls has increased, especially now that new value-added attributes such as organic practices, GMO-free, fair trade, eco-friendly and others have become increasingly important in marketing food products. Traceability is no longer just a marketing tool, but a requirement imposed by consumers and governments. It is linked to food safety as food is processed in systems with widely varying production standards and usually travels greater distances to markets, crossing borders and cultures (Eckschmidt et al., 2009).

Food traceability refers to systems that enable consumers, producers and regulatory agencies to follow the path of a given food item in the supply chain from the end market back to its origins at the farm. The ISO (International Organization for Standardization), which develops voluntary international standards for products and services, defines traceability as the "ability to trace the history, application, or location of that which is under consideration" (Golan et al, 2004a). Traceability systems are a tool to help firms manage the flow of inputs and products to improve efficiency, product differentiation, food safety, and product quality (Golan et al, 2004b).

ICTs play a critical role in ensuring the quality of food products through computerized systems that record each step in the process, from cultivation and harvest to storage, transportation, marketing and delivering to final consumers. Electronic systems for tracking inventory, purchases, production and sales are becoming an integral part of modern agro-food systems. Traceability systems in the agro-food sector generally employ labels or barcodes for product identification. The need for accuracy and efficiency has prompted the development of new technological tools for traceability management.[36]

Traceability systems employ the use of a unique piece of data (e.g., order date/time, a serialized number), generally using a barcode or Radio Frequency Identification (RFID), which can be traced through the entire production flow. The traceability software can audit information at any point in the system to find a particular product or transaction. Traceability has enabled rapid source identification and recall for plant or animal food products that

[36] One of the most promising alternatives to traditional solutions is Radio Frequency Identification (RFID) technology (Gandino et al, 2009).

may have been contaminated. Moreover, adopting a traceability system can increase production efficiency by reducing paperwork and enhancing the ability to quickly generate reports and identify problems. Such systems can also reduce costs by improving inventory control, thereby reducing waste.[37]

Traceability systems are also used in the food processing sector, for instance, to promote Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Points (HACCP) in slaughterhouses, meat processing plants, packing and other industrial areas. Additionally, traceability systems are essential tools in the certification of geographical origin and sustainable production processes as well as in identity preservation and product marketing, which enable producers to earn price premiums for sustainable, certifiable, and identifiable specialty food products. Geographic Indication of Origin (GIO) products are certified as originating in a delimited territory or region where a noted quality, reputation or other characteristic of the good is attributable to its geographical origin (Giovannucci et al., 2009). The market for specialty food, environmentally and socially friendly products, though still relatively small, is well established in developed countries and is an increasingly important niche for LA agricultural producers. Traceability has a crucial role to play in tracking and certifying eco-friendly, fair-trade and GIO products and validating adherence to environmental standards. These trends are creating opportunities for value-added products in agriculture.

a. Current situation in Latin America and the Caribbean

Since 2006, many Latin American countries have adopted traceability systems[38], mainly to increase the international competitiveness of their exports. This is a work in progress as producers and local farmers are still learning about and just beginning to implement traceability systems. Systems for domestic markets are much less developed. According to Thomas Eckschmidt, founder and CEO of PariPassu, a Brazilian traceability advocate and solutions provider, the gap is much wider in Latin America between the large, modern operations focused exclusively on exports and smaller farms that sell primarily to domestic markets (see box III.7). The

[37] For examples of available traceability systems see HarvestMark http://www.harvestmark.com/solutions.aspx developed by YottaMark and the Demand Driven Supply Chain and Business Intelligence http://www.getapp.com/demand-driven-supply-chain-and-business-intelligence-application developed by One Network Enterprises.

[38] Since 2005, it is mandatory in the European Union to use traceability systems for all food that go to the market. In the U.S. and Canada it is optional. However, since 2002 the U.S. has had bio-terrorism laws that put severe restrictions on imported food.

lack of computers and Internet access are challenges, as are the lack of understanding of what traceability is and why it matters to the grower.[39]

b. Relevant cases

It is worth noting that even though countries started implementing traceability systems to be more competitive at the international level, they are now extending traceability to domestic markets. The Brazilian supermarket chain Pão de Açúcar offers their clients the ability to find the farm that produced the food they sell, right from its website.

In Uruguay the Ministry of Livestock, Agriculture and Fisheries (MGAP) has created a compulsory national traceability system for livestock, the *Sistema Nacional de Información Ganadera* (SNIG)[40], comprised of more than 75,000 participants in the agricultural and industrial sectors, including producers, intermediaries, livestock auctioneers and slaughterhouses. In a gradual process that began with the individual radio frequency identification (RFID) and registration of all calves born after 2006, and culminated in July 2011 with the inclusion of the rest of the livestock population, SNIG now has information on more than 11.5 million animals in its database (Rebufello et al. 2011).

In Chile**,** agricultural exporters face the challenge of complying with the high standards required by European markets to ensure the safety and traceability of food products. Chile aims to consolidate and improve its position as a leading exporter of food products, so the need for product traceability has led to the creation of the Food Traceability Project, funded by the Implementation Fund of the EU-Chile Association Agreement. The main goal of this project is to develop a national traceability system for foodstuffs to guarantee compliance with international standards. The centre's laboratory has invested in state-of-the-art equipment worth nearly 1 million Euros. It uses more than 90 analytical tests for fruit, meat, milk, salmon, water, wine and other products.[41] Both Brazil and Chile have developed eco-labels for marketing products to environmentally-conscious consumers.[42]

Food Extra is a social network created in Argentina that was built to connect food consumers and food producers. Traceability is central to

[39] http://www.freshfruitportal.com/2010/11/09/connectivity-a-key-hurdle-for-traceability-in-latin-america/
[40] www.sing.gub.uy
[41] See more details http://ec.europa.eu/europeaid/documents/case-studies/chile_food-traceability_en.pdf
[42] A summary of the Chilean experience can be found in Ayala (2010).

Food Extra's purpose. Food Extra provides consumers with information about processing methods and product origin. It provides consumers with information such as product origin, production and processing methods, and details about the company(ies) involved. Users can write comments and product reviews. Food Extra is also a forum where the various players in the food chain can interact and forge trade relationships.

Supermarkets are now dominant players in most of the food sector in Latin America, having increased their retail market share from an estimated 10-20% in 1990 to 50-60% in 2000. Supermarkets are engines of market development and are contributing to the adoption of technologies such as traceability (Reardon and Berdegue 2002; Reardon, 2009).

Box III.7

The PariPassu traceability system in Brazil

PariPassu is a provider of technology solutions for agriculture and has focused on traceability for the last three years. Its name means "step-by-step" in Portuguese (not to be confused with the Latin phrase that is used as a financial term for "on an equal footing"). According to Thomas Eckschmidt, founder of PariPassu, it reflects the core concept behind traceability: start simple and keep it simple.

In 2010, PariPassu moved into new sectors such as beef, pork, chicken and eggs, based on the expertise it developed in traceability systems for honey and seafood. PariPassu's revenues have been growing 40% annually. They were the winners of the Successful Entrepreneur Award for 2010.[a]

Resources: See The Little Green Book of Food Traceability: Concepts and Challenges. Originally published in Portuguese, it is now available in English and a new edition is currently under preparation.

[a] The award is the result of a partnership between Pequenas Empresas & Grandes Negócios ("Small Companies & Big Business", a monthly magazine with a weekly television program) and the Entrepreneurship and New Business Center of the Getulio Vargas Foundation, sponsored by Visa.

c. Potential and current challenges

In countries that are already using traceability for their exports the next step is to offer local consumers the same ability to trace their food. This process will be easier for products sold at supermarkets that have the technologies to process the information. However, in some countries there is a cultural preference on the part of consumers to buy fresh products in traditional markets. It would be valuable to promote the modernization and technological development of these markets as well.[43]

[43] Useful references are http://www.regoverningmarkets.org/, http://www.freshfruitportal.com, http://www.omafra.gov.on.ca, and http://www.agrositio.com/. See also Vorley and Proctor (2008). http://mitsloanblog.typepad.com/springtrip2010/page/3/.

In most of Latin America, food comes from small farmers who do not possess the resources or expertise to implement high-tech tracing systems. Access to the Internet, computers and the know-how to apply them to farming are the biggest hurdles in expanding traceability beyond the largest exporters.

When deciding how to allocate scare capital resources farmers tend to focus on investments in managerial and operational efficiencies; however producers must not let factors related to production keep them from moving forward on traceability solutions and controls or the transition will be more painful down the road (Eckschmidt et al, 2009).

Box III.8

The use of geographic information systems to differentiate eco-friendly products

The U.S. Geological Survey (USGS) Earth Resources Observation Satellite Data Center, funded by USAID, is assisting coffee producers in Latin America and Africa in the development of ArcIMS software-based certification and marketing systems.

In the Dominican Republic, Codocafe, the Dominican Institute for Agrarian and Forestry Research, coffee cooperatives, USAID, and the EROS Data Center are working together to implement certification and marketing tools based on agricultural practices and conservation and biodiversity protection standards, using databases and tools provided by ArcGIS and ArcIMS.[a] The ArcIMS application developed by the project contains data and geo-referenced positions of more than 2,000 farms producing specialty coffee, or with the potential to do so.

Individual coffee farms are mapped with handheld GPS devices and a wide range of data is collected for each farm, including geographic and climatic conditions, socioeconomic data, and production information related to harvesting periods, certification issues, and types of protective trees. The data are converted to digital maps and displayed together with other spatial information, such as protected areas, forest cover, shade relief, topography and hydrography. Other specialty coffee online mapping projects initiated by EDC in Peru and Ethiopia follow a similar approach (Vorley and Proctor, 2008).

Thanks to these technologies, coffee traders in the United States or Europe can consult the Dominican Republic ArcIMS application to identify farms in specific locations, obtain contact information and request product samples. Government officials, scientists and other users with different needs can access the system to find out things like which coffee farms are located in areas at altitudes unsuitable for coffee production, which farms have received subsidies or which have been affected by specific coffee pests.

Source: Prepared by authors.

[a] *ArcGIS is a system for designing and managing solutions through the application of geographic knowledge. ArcIMS (standing for Arc Internet Map Server) is a Web Map Server produced by Esri (http://www.esri.com/).*

D. Enabling impact: trade and finance

To be competitive in a market firms must be as efficient selling their products as they are producing them. Marketing and delivering a product are important sources of competitiveness and can represent most of the value added to some goods. In the case of agricultural products, the price paid to farmers tends infact to be a small fraction of the price paid by final consumers even for non-processed products.

The advances in marketing and trade made possible by ICTs – in essence, the rise of electronic trade systems (e-commerce) – represented a major innovation in most value chains in the course of the last decade. They enabled a significant change in the way firms do business both with other firms and customers, leading to efficiency gains and cost reductions. Electronic transaction processes became a new way for firms to increase operational efficiency and to build competitive advantage. In the case of agriculture, the United States Department of Agriculture (USDA) identifies four potential uses of electronic trade systems in the sector: information distribution, input supply, commodity trade, and logistics/supply chain management.

Compared to other industries, however, the use of electronic trade systems in the agrifood sector is rather low, especially in the case of business-to-consumers trade. Even though some wealthy regions have experimented an important transformation of the business environment in the agrifood sector, with the proliferation of small and medium firms selling directly to consumers on Internet, the reality of most developing countries is of a very limited use of this trade channel. Characteristics of agricultural products such as diversity and perishability seem to explain part of this moderate rate of diffusion. Other aspects such as the low access of farmers to Internet and the lack of standard measures to assure product quality and safety attributes have also be pointed in literature as possible reasons for a limited development of electronic trade in agrifood markets.

Beyond the suitable ICTs, other assets are required to make electronic trade systems work. One of them is the access of buyers and sellers to financial services that can be used to make electronic payments and transfers. The access of rural and agricultural population to banking and other financial services has been historically low in developing countries. The high distances to branches have been a major barrier, as well as cultural resistance and the informal status of a large share of agricultural enterprises and employees.

Table III.7
ICT uses and related technologies to enable agricultural business

ICT Use	Data origin	Data collection	Data storage/ management	Data access/ exploration	Data processing	Communication
Electronic trade systems	Private companies and users	Internet, intranet and extranet connected computers, fixed and mobile phones	Private websites, intranets and extranets powered by dedicated software such as Electronic Data Interchange (EDI)	Authenticated access to product information and trade services (orders, payments, tracking, etc.)	Dedicated software and devices, EDI	Two-way communication between private companies, their partners along the value chain and customers based on online forms, e-mail, instant messaging, chat, phone calls
Branchless banking	Private companies and users	Internet connected computers, fixed and mobile phones, cash machines, point of sale (POS) devices, payment cards	Private websites and POS devices	Authenticated access to banking information and services (transfers, payments, cash deposit and withdrawal, etc.)	Dedicated software and devices	Two-way communication between private companies and customers based on online forms, e-mail, instant messaging, chat, phone calls

Source: Prepared by authors.

Financial services have also been transformed by the emergence of ICTs. From the now customary Automatic Teller Machines (ATMs) to the management of supply chain information and payments using mobile phones, not only the transactions between businesses have been transformed, but also the way customers search and contract financial services, including loans. The results of the emergence of the called electronic finance (e-finance) include a lower level of intermediation and information costs and wider access to branchless financial services (either complementing or replacing usual banks' services). The impacts on rural areas, even though still limited, have showed the potential of these technologies to enable and stimulate economic transactions.

This section aims to analyze the uses of ICTs that can facilitate economic transactions in agriculture by making available to farmers and other actors in the value chain (including customers) more efficient forms of searching for products and prices, contacting providers and making contracts and payments. Two main uses of ICTs in agriculture are considered: electronic commerce and branchless banking. Table III.4 shows the main ICTs related to these uses. Internet (in business-to-consumers) and intranet or extranet (in business-to-business) are the most common channels for electronic transactions but mobile phones and other devices (in points of sale, for instance) have been gaining importance in the last years. Security is of paramount importance in these areas and has been both challenged and improved by ICT developments in e-commerce and e-finance over the last years.

1. Electronic commerce

Commonly known as e-commerce, electronic commerce encompasses a broad range of activities, including electronic trading of goods and services, online delivery of digital content, electronic fund transfers, auctions, collaborative design and engineering, online sourcing, public procurement, direct consumer marketing and after sales services (Timmers, 1999). The amount of trade conducted electronically has grown rapidly over the past fifteen years. It has benefited from a number of ICT innovations in electronic funds transfer, supply chain management, online transaction processing, electronic data interchange, inventory management systems and automated data collection systems.

The food industry uses e-commerce for both direct sales to consumers, called business-to-consumer (B2C), and business-to-business (B2B) transactions. B2B is the most highly developed and widely used of the two (Kinsey and Buhr, 2003). In the United States, it was about ten times larger than B2C at the end of the 1990s (Timmers, 1999). Also in that country, where e-commerce is growing rapidly, sales in the third quarter of 2010 accounted for 4 percent of total retail sales, according to a Census Bureau report (Rampell, 2010). By the year 2000, one in 25 U.S. farms had already bought or sold agricultural products on the Internet and this figure was growing rapidly (Mueller, 2000). E-commerce is substantially lower in most LAC for the reasons discussed below.

a. Current use in Latin America and the Caribbean [44]

The estimated value of transactions through electronic commerce (B2C) in Latin America amounted to US$27.6 billion in 2010 and was expected to reach US$34.5 billion in 2011 (this figure represents 0.3% of GDP, but is growing by 20% to 40% a year). If current trends continue, e-commerce would account for between 10% and 15% of GDP by the year 2020. Much of the impetus behind electronic commerce in the region currently stems from the tourism industry (mainly the sale of airline tickets), followed by the purchase of books, music and electronic devices. The sale of food and inputs for agriculture plays a limited, but expanding, role. Brazil is the Latin American leader in e-commerce with 61% of the total in the region, followed by Mexico (12%), Chile (5%), the Bolivarian Republic of Venezuela and Argentina.

Table III.8
B2C total consumption in Latin America and the Caribbean
(in millions of US dollars)

	2005	2006	2007	2008	2009
Brazil	2 270	3 541	4 899	8 573	13 230
Mexico	567	868	1 377	2 010	2 625
Chile	243	472	688	920	1 028
Venezuela (Bolivarian Republic of)	253	490	822	788	907
Argentina	241	378	562	733	875
The Caribbean	387	565	660	755	868
Central America	189	360	499	564	637
Puerto Rico	344	484	445	490	588
Colombia	150	175	201	302	435
Peru	109	146	218	251	276
Others	131	165	203	261	307
Total	4 885	7 542	10 573	15 645	21 775
Growth rate		54.4 %	40.2 %	48.0%	39.2%

Source: LatinTec Info (2010).

In per capita terms, Chileans are the highest online spenders in the region, according to data from the Information Society Indicators (ISI) gathered by the consulting firm Everis in 2010. Retail sales reached US$107 per

44 The eMarket website (www.emarketservices.es in Spanish and www.emarketservices.com in English), is a non-profit initiative aimed at promoting the use of e-commerce. It includes a useful global directory that offers higher eMarketplace security assurances and information about what they are and how they work. It also provides useful suggestions and tips related to sectoral and legal issues.

capita in Chile in the first quarter, representing an increase of 48.6% over the previous year. Second was Brazil (US$49), followed by Argentina (US$39), Mexico (US$14), Peru (US$14) and Colombia (US$12). There is a close correlation between per capita online expenditures and computers per 1000 of population with Chile leading at 370 computers per 1000, followed by Brazil (262), Argentina (258), Mexico (209), Peru (131) and Colombia (116).

b. Relevant experiences

There are many interesting experiences of e-commerce of agricultural inputs and products in the region; some of them are detailed in the following paragraphs.

In Argentina,[45] is a well-developed website for buying products and services, including agricultural inputs, machinery and veterinary services. It provides useful market information, quotes from the local grain exchange and news about commodities important to Argentina such as wheat, meat and sunflower seeds.

In September 2011, the Jumbo supermarket chain in Chile launched an innovative method of selling through online stores set up in Santiago Metro stations. The initiative, called Jumbo Mobile,[46] allows subway users to select from over 100 products which, after being scanned and ordered by consumers through their smart phones, are delivered to their homes. These virtual stores offer a wide variety of items from dairy, frozen foods, bakery goods, meat, and beverages to cleaning products and perfumes.

In Brazil, there are a large number of agricultural websites, several of which provide electronic commerce services. Among them is RURALBR,[47] Cade Rural,[48] Agricola e Pecuaria,[49] Agron,[50] Rede Rural Centro,[51] and Comercial Rural.[52] It is also worth mentioning Rural Centro Mercado,[53] a

45 www.agrositio.com.
46 http://www.jumbo.cl/supermercado/jumbomobile/.
47 http://www.ruralbr.com.br/.
48 http://www.caderural.com.br/v2/.
49 http://www.agricolaepecuaria.com.br/.
50 http://www.agron.com.br/.
51 http://www.ruralcentro.com.br/.
52 http://www.comercialrural.com.br/
53 http://www.mercado.ruralcentro.com.br/

showcase for products and agricultural inputs, which are presented with additional useful information.[54]

Box III.9

Latin American Institute of Electronic Commerce, ILCE

ILCE is a network of organizations promoting e-commerce in LAC. E-commerce chambers created in the region, including those in Argentina, the Bolivarian Republic of Venezuela, Brazil, Colombia, Chile, the Dominican Republic, Ecuador, Mexico, Paraguay, and Peru. The Spanish Association of Electronic Commerce and the Association of Electronic Commerce and Interactive Advertising of Portugal are also members of ILCE.

The main initiatives of the Institute include an "e-commerce day" for each country and the region as a whole, e-commerce awards, the development of an e-business community, training and capacity building, research on the digital economy, a regional dissemination program and a number of activities promoting links with Europe and the United States.

Source: ILCE.

c. Potential and current challenges

The development of e-commerce is uneven across the region. The most mature markets, in terms of e-commerce's contribution to GDP, are Brazil at 0.84% and Chile at 0.64% (Visa and América Economía, 2010). Some of the potential advantages of e-commerce for agriculture are (Wilson, 2000):

(i) Increasing market reach with limited investment by allowing participants in the agro-food chain to establish links and transact business irrespective of geographic location;

(ii) Facilitating improvements in transport and logistics by strengthening links between producers, processors and retailers;

(iii) Improving price transparency. Online access to product and price information facilitates comparison shopping, promoting price transparency. Price differentials resulting from geographic location are also likely to diminish because of increased competition;

[54] The full list of websites related to e-commerce and related activities can be found at http://www.chuto.net/d/Agronegocios/Portais_agropecuarios/.

(iv) Encouraging the formation of online cooperatives. From the farmer's perspective e-cooperatives can provide a way to reduce costs through pooled purchasing. For example, Lavouras (2000) suggests that grower groups can obtain 30% or more in savings on chemical purchases through e-marketplaces and buyers report savings of 25-50% on orders; and

(v) Reducing recordkeeping and transaction costs. Specialized vendor management software can provide single billing for purchases.

Impediments to the development of electronic commerce in agricultural activities include inadequate access to the Internet, lack of credit cards, distrust of online payment systems and the fear of getting something other than what was purchased. Despite their high rate of economic growth, rural areas in Latin America remain predominantly offline. Providing e-commerce services will require additional investments in technology. In spite of these barriers, Latin American businesses are gradually moving ahead in adopting e-commerce and each new development will further increase the volume of goods and services traded through the Internet (Visa and América Economía, 2010).

2. Branchless banking and rural finance

Of all the changes occurring in rural areas, the introduction of mobile devices and the development of branchless banking are probably among the most radical; they are changing the way financial services are provided and accessed. The depth and scale of change is such that it has led some experts to predict that ending financial exclusion is becoming a real possibility with the use of ICTs.[55]

As noted by the e-Agriculture Policy Brief (2009), mobile telephony and other ICT tools used in rural areas effectively reduce the distance between individuals and institutions, easing the exchange of information. The mobile phone is no longer just a personal communication device, but an essential means of communication for taking advantage of economic and social opportunities. The mobile phone is becoming the most important ICT tool in rural areas.[56]

[55] One reason for this optimism has been the success of programs like M-Pesa in Kenya (with an outreach of 80% of the population) and FINE in India (30 million clients and growing rapidly).

[56] The number of mobile phone subscriptions in developing countries has increased from 200 million in 2000 to 3.7 billion in 2010 and the number of Internet users has grown more than tenfold (World Bank, 2011: 4). This trend is seen in all economic sector.

Table III.9
Instruments used in branchless banking

Type of instrument	Key benefits	Examples
Magnetic strip card	Many people already know how to use these cards, which are becoming quite popular, particularly in LAC. Use of cards in point of sale (POS) devices is fairly intuitive. Not dependent on telecommunications.	Banking correspondents in Brazil, Chile, Colombia and Peru.
Cell phone	No need for cards and POS devices if users already have a cell phone. Customers can check balances on their phones. Use of ATM or POS terminals possible, but with equipment adaptation.	M-PESA in Kenya and Tanzania. G-Cash in the Philippines, Eko in India.
Magstripe card + cell phone	Mobile banking customers have the option of using the card at any existing card-acceptance device (ATM, POS).	Smart Money in the Philippines; MTN Banking and WIZZIT in South Africa.
Smart card	Account balances can be held in the card, so transactions can be authorized off-line (devices need to upload transactions from time-to time). This cuts down on communication costs and the smart cards work where there is limited telecom coverage.	Net1 UEPS in Africa, FINO in India (both used mainly for government payments)

Source: Mas (2009).

It is estimated that in 2009 there were 181 million registered customers in branchless banking, a figure that by 2010 had risen to 238 million; an increase of 31% in just one year. A similar expansion took place in the number of active clients, which rose from 137 million to 185 million in the same period.[57] Behind this growth is the rapid diffusion of the Internet and mobile telephony. There are four typical operations in branchless banking: person-to-person remittances (P2P); payment systems (P2B and G2P)[58]; e-commerce; and other financial services.

a. Current use in Latin America and the Caribbean

A report by Wireless Intelligence found that Latin America trailed only the Asia-Pacific region in terms of mobile use in the second quarter of 2010. The 530 million mobile phone connections in Latin America represent 11% of the world's users, according to the study. The region surpassed Western Europe (515 million users) for the first time and also exceeded the number of connections in Africa (The Latin Americanist, 2010).

57 The figures are approximate but give an idea of the magnitude of this process. See Bold (2011).
58 People-to-business and government-to-people, respectively.

Only about one-third of the population in Latin America and the Caribbean has access to formal financial services, but 80% has access to mobile phones. This represents a significant opportunity for extending financial services to millions of low-income customers in the region (IFC, 2010). It must be pointed out, however, that mobile phone coverage in rural areas is substantially lower than in urban areas.[59]

Table III.10
Latin America: fixed and mobile telephony market share
(percentages of total phone subscribers)

Year	Fixed phones	Mobile phones
1998	74	26
2000	55	45
2002	47	53
2004	35	65
2006	24	76
2008	19	81
2010	16	84

Source: BuddeComm Research (2010) based on ITU, Global Mobile and industry data.

Although the development of branchless banking has been significant in Latin America, it is still lower than in other regions. Of the 97 initiatives accounted for in Bold (2011), 19 are located in Latin America and the Caribbean. Africa and Asia have taken the lead in branchless banking and their systems are models in the microfinance industry. This is reflected in the list of "Global Mobile Awards" winners, the prestigious annual competition organized by the GSMA.[60]

b. Relevant cases

The need to expand bank coverage in both urban and rural areas has led many banks in the region to explore different forms of branchless banking. One of them consists in the opening of counters in existing small businesses such as grocery stores, drugstores and post offices,

59 The figures for the other regions are as follows: East Asia & Pacific 83%, Europe and Central Asia 79%, Middle East and North Africa 69%, South Asia 47% and Sub-Saharan Africa 42%.

60 In 2009 and 2011 the "Best Mobile Money Service for the Unbanked" title was awarded to M-PESA (Kenya, Safaricom), while the best use of mobile technology for social and economic development award was given to Nuance Communications, Airtel India Consumer T9 Vernacular. In 2010 M-PESA won the "Best Mobile Service" title, whereas the award for the best use of mobile technology for development went to the Grameen Foundation, MTN Uganda and Google.

among others, connected to traditional branches. These counters allow clients to realize simple bank operations (withdraws, deposits, transfers and payments) using electronic cards delivered to them even if they do not have a bank account. This service is increasingly demanded in rural areas due to the saving of time and costs related to travelling, which clients would have to afford in case they needed to visit a branch to realize those operations. Moreover, it extends banking services to people that otherwise would not have access to them at all.

Prominent examples of branchless banking in LAC are in Brazil (*Bradesco, Caixa Econômica Federal, Banco do Brasil* and *Banco Lemon*). In October 2009, there were 149,507 banking correspondents in Brazil, many of whom had delivery operations for loans and credit cards, among other services. More than 50,000 of these agents were authorized to open and manage credit card deposits. In Colombia an experience in this sense is called *Bancolombia A la Mano*[61] and works since 2006, currently present in almost 1,200 small businesses. In Chile a similar experience is called *Caja Vecina*, developed by BancoEstado[62] since 2006, being currently present in more than 6 thousand places all over the country.

In the Bolivarian Republic of Venezuela, a start-up company called Diemo has launched a mobile banking operation with GSM network provider Digitel. The service gives rural, generally poor residents the ability to transfer money wirelessly via a cell phone to a store where a third party can receive cash. The service is available to any of Digitel's six million customers in the Bolivarian Republic of Venezuela and in Colombia.

In Peru, Afi Foundation, with support from the Spanish International Cooperation Agency (AECI), is assessing ASOMIF (Association of Microfinance Institutions) partners: *Caja Rural de Ahorro y Crédito Nuestra Gente*; *Caja Rural Señor de Luren*; and *Edpyme Solidaridad y Desarrollo Empresarial*. The objectives of the project are to identify barriers to the use of mobile phones for financial transactions and ways to improve mobile access to branchless banking.

In Ecuador, the central bank plans to launch a mobile money service. The program, called *Sistema de Pagos Móbiles,* is scheduled to begin this year and

61 www.grupobancolombia.com.

62 www.bancoestado.cl.

will, for example, allow customers to send money via a short message service (SMS) to a family member or to pay water and electricity bills via cell phone. Other initiatives in the region are *Tigo Cash*, in Paraguay; *NaranjaMo*, in Argentina; and *Oi Paggo*, in Brazil.

c. Potential and current challenges

Branchless banking and mobile telephony can greatly improve access to financial services for rural farmers. It has a number of advantages: (i) it can make it cheaper and easier to save, receive loans and make loan payments; (ii) it facilitates the collection and management of payments by input suppliers who, in turn, can use mobile money and other ICT tools to aggregate their orders and process payments; (iii) it can make it easier and safer for traders to manage transactions and make bank deposits; (iv) it enables large buyers to pay a very large number of producers faster as well as manage any credit they offer to such producers; (v) it facilitates payments for micro-insurance; and (vi) it increases the efficiency and reliability of voucher services for fertilizer or other inputs. An important benefit of branchless banking is that it enables producers and others in the value chain to more easily and cheaply receive remittances from family members and business partners to help them with cash flow (USAID 2010a).

Despite its promising future, branchless banking is still in its infancy in most LAC countries. Obstacles include high costs, particularly for the new generation of mobile phones, limited network coverage in rural areas, lack of technological skills, low awareness of the potential benefits, the limited availability of repair services and regulatory factors. However, it is expected that many of these barriers will gradually be overcome as a result of the intensive learning process currently under way. The success of initiatives in Africa and Asia will also help stimulate the implementation of mobile banking in the region.

E. Direct impacts: productivity and efficiency

Increasing agricultural productivity based on ICTs is linked to either the introduction of new, better inputs or an improved use of current resources. Increasing productivity based on the use of new resources is not possible to all farmers and regions since it depends on natural resources endowment. Productivity increments based on the better use of existing resources, in turn, are feasible to basically every farmer and also promote the parallel reconciliation of agricultural production with environmental preservation. The predominant strategy in this case includes a better knowledge of the complexity and spatial variability of biological and agricultural processes and the adoption of practices that recognize and take advantage of these particularities.

The complexity of agriculture can be visualized in any single farm with site-specific conditions whose result is a particular spatial variability regarding the possibilities of production. To the site-dependent conditions (weather, soil, water quality and availability, etc.) we can add the differences in the technological tools and skills managed by producers as well as the resources available in the system (technical support, financial options, social networks, etc.). All these sources of variability must be considered in order to understand the opportunities and challenges that constrain farmers' decisions at every moment. As a result, there is no "one-size-fits-all" optimal technology, even for a single farm, due to local and time-specific sources of variability. ICTs can help precise and understand these sources, identify patterns of behaviour in time and space and promote suitable practices, reducing uncertainty and increasing both productivity and profits in agriculture.

Previous sections have analyzed the uses of ICTs in agriculture that have an indirect impact on productivity and efficiency. This section will focus on the uses of ICTs more directly linked to the production process. One of such uses is precision agriculture, a set of ICTs and other technologies that promote a better management of the spatial variability of agriculture in order to make the use of inputs more efficient. Other ICT uses analyzed in this section are precision irrigation, pest and weed control and agricultural systems management. Table III.11 displays the main ICTs underlying each use.

Table III.11
ICT uses and related technologies to improve productivity and efficiency in agriculture

ICT Use	Data origin	Data collection	Data storage/ management	Data access/ exploration	Data processing	Communication
Precision agriculture, Precision irrigation and Pest and weed control	Mostly private companies but also public agencies such as Agricultural Innovation Institutes	Agricultural equipment, aircrafts and satellites equipped with Geographic Positioning Systems (GPS), sensors, digital cameras and scanners	Public and private websites and agricultural equipment powered by Geographic Information Systems (GIS)	Paid or free webpages and agricultural equipment; mapping, visualization and analysis of field variability, web-GIS	Simulation, risk and decision-support models, GIS	Online visualizations, e-mail and SMS alerts; agricultural equipment with variable-rate technologies
Agricultural management systems	Mostly private companies	Internet, intranet and extranet connected computers	Private websites, intranets and extranets powered by dedicated software	Authenticated access to transaction information and tools to plan and manage the business	Dedicated software such as Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM)	Two-way communication between the enterprise staff, partners along the value chain and customers based on e-mail, instant messaging, chat, surveys, phone calls

Source: Prepared by authors.

1. Precision agriculture

Precision farming, or precision agriculture (PA), is the management of spatial and temporal variability in order to increase economic returns and reduce environmental impacts (Blackmore, 2007). It primarily relies on five technologies: GPS, GIS, remote sensing, variable rate technologies (sensors, controllers and others) and applications for the analysis of geo-referenced data, including geo-statistics, spatial econometrics multifactor analysis and cluster analysis (Chartuni et al. 2007).[63] Together, these technologies speed up the decision-making process in agriculture. Precision agriculture first emerged

[63] It should be pointed out, as it is argued later in this paper, that it is possible to think on a “softer” approach to precision agriculture with less intensive use of these technologies.

in the United States in the early 1980s. Other precursor nations were Canada and Australia. In Europe, the United Kingdom was the first to adopt PA, followed by France.

a. Current situation in Latin America and the Caribbean

The use of PA varies widely by subregion in Latin America and the Caribbean with significant adoption in the Southern Cone countries, particularly in Argentina and Brazil. It has spread mainly in extensive agriculture - wheat, corn, soybean, and sunflower production. It has also been adopted in specific products and regions in Chile (fruit production and viticulture), in Mexico (in the north of Sinaloa, Sonora), in southern Paraguay and in some areas of Uruguay. This uneven adoption is partly due to its technical and capital requirements (see table III.12).

Table III.12
Adoption of precision agriculture tools in South America, 2008

Countries	GPS guidance for ground applicators	Planting monitors	Yield monitors	Variable rate technology (planting and fertilizer applicators)	Automatic Pilot
Argentina	9 000	8 000	4 500	1 000	400
Brazil	18 000	6 000	2 000	1 300	1 200
Other countries	2 000	1 200	1 000	50	50
Total	29 000	15 200	7 500	2 350	1 650

Source: *Bragachini (2011: 23), INTA, Precision Agriculture project.*

An important consideration is to what extent information and communication technologies are scale neutral or scale biased. An innovation is scale neutral if it is divisible across an entire range of outputs. For example, the introduction of new seed varieties and fertilizers is a scale neutral innovation. Scale-biased innovations, such as tractors and wells, are not divisible. What about ICTs? Some of them, like PA, may require a minimum scale and an important question is to what extent this could be achieved through a process of cooperation between small-scale producers.

According to Norton and Swinton (2001), precision agriculture is adopted first in areas with large farms and high capital investment per hectare. An important issue, increasingly discussed, is to what extent the principles of PA could also be applied to other countries of Latin America and the Caribbean where the average farm is smaller. As Cook et al. (2003) argue, "while the information technology that lies at the heart of PA is clearly unattainable and inappropriate to all but a few farmers in the developing world, the principles of using spatial information to reduce uncertainty in a rapidly changing world has much to offer. Indeed some of the principles within PA may prove essential to the sustainability of agriculture in the face of increasing pressures from agriculture in developed countries."

b. Relevant experiences

Argentina is the largest user of precision agriculture in the region. Its adoption there began in early 1996 with the launching of the PA program at the Manfredi experimental station of INTA. This program was expanded to the national level in 1999 and currently includes five experimental stations in four provinces (Buenos Aires, Córdoba, Santa Fe and Entre Ríos) with headquarters at Manfredi.

The growth in the use of PA technologies in Argentina from 1997 to 2010 is shown in table III.13. In 2009, 38% of the monitors for sowing and 25% of the machinery for harvesting were equipped with precision farming tools. Argentina is also a leader in the regional production of agricultural machinery used in precision agriculture. In 2010, the value of Argentinean exports of agricultural machinery was US$260 million (Bragachini, 2010).

Table III.13

Adoption of precision agriculture tools in Argentina, 1997-2010

	1997	2002	2004	2006	2008	2010
Yield monitors in combines	50	600	1300	2500	4500	7450
Variable rate technology[a]	3	12	40	420	1000	1804
Variable rate fertilizer application (liquids)	0	0	0	80	335	600
Planting monitors	400	1500	2200	4200	8000	12560
GPS guidance systems for airplanes	35	230	450	550	690	800
GPS guidance for ground applicators	0	500	3000	5000	9000	12298
Automatic pilot	0	0	3	50	400	1150
Chlorophyll sensor for VRA-nitrogen	0	5	7	12	15	27

Source: Bragachini (2011: 23), INTA, Precision Agriculture project

[a] *Planting and fertilizer applications (solids)*

In Brazil, Aquarius Project[64] started in 2000 between the private and state enterprises Cotrijal, Massey Ferguson, Yara, Stara and Federal University of Santa Maria from the NEMA and soil department. The aim was the development of an entire cycle of Precision Agriculture (PA). It started with 156 hectares in two areas in the south of Brazil (Schmidt and Lagoa); in 2011 it managed sixteen areas at Alto Jacui with a total area of 726 hectares. The project tested PA tools on the field, making the results available to all producers and today, with 11 years of accumulated information, it is the highlight in Brazil in this area. The future aim is to integrate new sensors, management of soils and plants in real time.

A key program in the Southern Cone is the joint initiative between PROCISUR and the Interamerican Institute for Cooperation on Agriculture (IICA). They have been working together since 2000 with the objective of disseminating and developing precision agriculture technologies that are suited to conditions in the region. The first phase of this program culminated with the publication of the book *Agricultura de Precisión: Integrando conocimientos para una agricultura moderna y sustentable* (Bongiovanni et al, 2006).

Box III.10

The Precision Agriculture Network[a]

Since 1997, INTA of Argentina has led and coordinated the Precision Agriculture Network, which supports the development of PA technology for crop management. The network seeks to transform PA into a practical tool that more widely spreads the benefits of the increased agricultural productivity, competitiveness and enhanced social and environmental sustainability offered by these technologies.

Every year INTA Manfredi organizes an international event (one of the largest in the world) featuring a high quality program of courses and exhibits. AgroShowRoom in July 2011 featured more than 50 speakers and presented 12 management courses in PA software. The event, attended by over 2500 people from 17 countries, included 90 exhibiting companies.

Source: INTA.

[a] *http://www.agriculturadeprecision.org/).*

In other countries, the use of PA is still incipient. However, there is increasing interest and a number of initiatives are under way. In Colombia, for example, there was a course on precision agriculture in 2007 and a

64 http://w3.ufsm.br/projetoaquarius/

special issue of the *Revista Nacional de Agricultura* (No 949, June 2007) was devoted to PA. There is a project under development in Peru to interpret the information from low-altitude images, aimed at improving agricultural efficiency and productivity. It involves remote-sensor imagery from unmanned aircraft using various types of radio remote control, multispectral imaging and geographic positioning systems.[65] There are also signs of increasing interest in these technologies from private sector investors.[66] Similar interest exists in other LAC countries, with a number of initiatives being undertaken in Costa Rica, Cuba, the Dominican Republic, Mexico and Panama, among others.

c. Potential and current challenges

A major advantage of precision agriculture is that economic and environmental goals are simultaneously achieved. Reducing the use of agricultural inputs reduces costs and negative environmental impacts, and applying the right amount of inputs in the right place at the right time benefits crops, soils and groundwater. Some studies have shown that producers using PA have reached lower costs compared to other producers, due to a more accurate use of inputs. On the long term these producers also present a lower environmental impact, including a reduction in the level of resistance of pathogens, thanks to a more rationalized use of agrochemicals (Bongiovanni et al, 2006).

Consequently, PA has become a key component of sustainable agriculture. In general terms it has been attested that the use of PA provides a better understanding of the intrinsic variability of agriculture, giving farmers and other agents of the agrifood chain the possibility to develop a differential management of agricultural systems. Benefits from PA in the literature surveyed include:

- Local development of appropriate technologies suitable for local requirements;
- Better control of the cultivation area by knowing the variation of grain yield by location;
- Rational use of inputs to maximize the returns;

[65] For more details see the following link: http://elcomercio.pe/edicionimpresa/html/2008-03-07/impulsan-agricultura-precision-mejorar-produccion-cultivos.html

[66] See, for example, the opinion of Guillermo Aguilar of Neoag Peru, a firm working on the implementation of modern technologies: http://www.agroeconomica.pe/tag/agricultura-de-precision/

- Lower environmental impact and improved soil quality over time;
- Prioritization of investments in inputs in areas where the potential yield is higher, economic returns;
- Better decision-making management by using a greater flow of information;
- Increased value of the rural property;
- Reductions of the pesticides resistance subsequent to the use of more rationalized doses.

Despite these results, there are a number of obstacles to implementing PA, particularly in its capital-intensive form. The high-tech model is not well-suited to the circumstances faced by small-scale farmers in developing countries. Obstacles include low levels of literacy among farmers, lack of equipment and land ownership systems based on smallholdings. Another limitation is the availability of simulation models for crops cultivated by small farmers. One key question is to what extent aspects of PA can be applied to small farms, bearing in mind the above-mentioned constraints.

Many small farmers are actually users of precision agriculture without knowing it, to the extent that they are aware of the spatial and temporal variability within their holdings that influence their crops and make appropriate management decisions to take advantage of that variability. Cook et al (2003) argue that, "A commonly stated reason for low adoption rates of precision agriculture (PA) is that its benefits are insufficient to justify the costs. Ostensibly, this seems to preclude any possibility of PA in developing countries, where profitability is much lower than in developed economies, and where there is only a localized prospect of supporting high technology. We question this assertion, and postulate that the basic purpose of PA —to provide spatial information to reduce the uncertainty— far from being a luxury, could be viewed as essential to accelerate change in the developing world, even if it is used in a different form to that offered in Europe or North America."

This point is supported by Blackmore (2007): "Although sophisticated technology exists for implementing Precision Agriculture that does not mean that it can only be implemented that way. It can also be done using basic technology, such as a computer to record the information or even information recorded manually. The important thing is the ability to measure, to some extent, the factors that increase the efficiency of a crop and to evaluate them in such a way as to allow the manager of that crop to take decisions."[67] Blackmore provides examples from Sri Lanka and Tanzania that are very relevant in this respect.[68]

2. Precision irrigation

Using water resources in a more efficient way does not concern only to agriculture but it is part of a much broader preservation strategy that comprises all economic sectors and households. Nonetheless, since agriculture ranks first in water consumption amongst all sectors, its production practices regarding water use matters for the preservation goals that governments and international organizations have set for the next decades. Some of these goals refer to make a much more efficient use of existing water sources, to develop mechanisms to properly calculate the economic value of water and other ecosystems and to support innovation that lowers water consumption. In the case of agriculture such innovations include improving cultural practices to avoid water waste, using biotechnology to create varieties of plants more resistant to water stress, and integrating ICTs in agricultural equipment to increase the knowledge about the real needs of plants, thus developing irrigation systems to meet these requirements. Finally, closing the gap between low and high productivity areas is also a condition to make water use more efficient in agriculture.

In this context, Precision Irrigation (PI) emerges as a technological option to reach both high productivity levels and better water preservation practices. It is defined as site-specific water management, specifically the application of water to a given site in a volume and at a time needed for optimum crop production, profitability, or other management objectives. It is described as an available agricultural practice, but authors also mention that costs of implementation can be an issue (Camp ,2006; Pierce, 2010). In water deficient places PI is reaching particular relevance. Like in the case of PA, precision irrigation can also show results in a low-tech version. In effect, this practice can be applied to non-automatic systems such as drip irrigation, simply by grouping and irrigating crops and varieties according

67 Translated from RH. Blackmore (2007) includes a very useful one page path to implement profitable Precision Agriculture ("La ruta para una agricultura de precisión rentable").

68 See also the discussion about precision agriculture in CTA Update (2006), which includes a number of examples from developing countries. In the Q&A section of the Update, Dr. Jetse Stoorvogel of Wageningen University and Research Centre in the Netherlands takes the debate a step further and argues that many small-scale farmers in developing countries are already using the principles of precision farming with limited use of high-tech equipment.

to their drought tolerance. Variation in water requirements for a same crop may be due to differences in variety and age or caused by local conditions like climate and soil characteristics.

a. Current situation in Latin America and the Caribbean

Even though LAC countries have plenty freshwater resources and precipitation levels around 50% over the world average, distribution of these resources in time and space is an issue and almost one fourth of the region territory presents an arid or semi-arid climate while recurrent floods and storms affect countries in all subregions (Sotomayor et al, 2011). Regional agriculture has historically developed according to this uneven distribution of water resources. Irrigation policies only started being implemented in the beginning of the 20th century, basically in the form of out-farm and in-farm infrastructure building (dams, canals, surface irrigation systems, etc.).

The green revolution in the 1960s and 1970s brought about the emergence of more advanced, sprinkler or localized irrigation systems coupled with the intensification in the use of agrochemicals. The last decades have witnessed the development of automated electric and hydraulic irrigation systems in the region, and more recently, computerized and GPS-equipped systems. These techniques have been initially adapted from other countries by the Agricultural Institutes of Technology (INIAs) in the region and transferred to farms via extension programmes.

There is no information on the area equipped for precision irrigation in the region, but Aquastat database[69] provide some data on the area equipped for all types of irrigation. These data refers in most cases to the middle of 1990s though. Countries have their own estimation for the irrigation potential, taking into account variables such as land resources, water availability and other economical or environmental aspects. Aquastat Data shows that the percentage of irrigation potential equipped for irrigation reaches an average of 29% in LA (64% in Mexico) and that the percentage of the cultivated area equipped for irrigation reaches 23% (82% in Chile).

69 http://www.fao.org/nr/water/aquastat/dbase/index.stm.

b. Relevant experiences

The Food and Agriculture Organization (FAO) has developed AquaCrop, a water productivity-modeling tool that simulates how crops respond to different amounts of water. The software has been used mainly in Asia and Africa. In Latin America, it has been used in the Plurinational State of Bolivia to assess quinoa crop response to water stress (see S. Geerts et al. 2009). The AquaCrop software, more fully described in box III.11 below, and its operating manual can be downloaded free of charge at the FAO website.

Box III.11
AquaCrop: Simulating crop yield response to water

Estimating attainable yields under water-limited conditions is an ongoing challenge in arid, semi-arid and drought-prone environments. To address this need, FAO developed AquaCrop, a yield-response–to-water model that simulates attainable yields of the major herbaceous crops. The model attempts to balance accuracy, simplicity and robustness. It uses a relatively small number of input variables requiring simple methods for their determination. AquaCrop can perform the following tasks:

- assess the effect of water limitations on crop yields at a given geographical location;
- compare attainable yields against actual yields for a field, farm, or region to identify the yield gap and the constraints limiting crop production;
- assess historical rainfed crop yields and schedule the water deficits and the supplemental irrigation that is needed;
- develop irrigation schedules for maximum production (seasonal strategies and operational decision making) under different climate scenarios;
- evaluate the impact of fixed-delivery irrigation schedules on attainable yields;
- simulate crop sequences and conduct analyses of future climate scenarios;
- optimize the use of limited water resources and apply economic, equitability, and sustainability criteria;
- evaluate the impact of low fertility and of water-fertility interactions on yields;
- assess actual water productivity (biological and/or economic) from field to regional levels;
- support decision-making on water allocation and other water policy actions.

AquaCrop is mainly intended for technical staff working in extension services, governmental agencies, NGOs and farmer associations. The software is also of interest to scientists and for teaching purposes as a training and education tool related to the role of water in determining crop productivity.

For details of the model, related literature, software, applications and links, see the AquaCrop website: http://www.fao.org/nr/water/aquacrop.html

Source: FAO.

Other initiatives in Latin America include Irriga (Brazil) and INNOVA Project (CORFO/INIA) in Chile. The first is an interesting example of an integrated irrigation system in which the inputs are measured and monitored at local and regional level and in experimental or tested fields (see box III.12). INNOVA, in turn, developed another valid tool to minimize the management errors in irrigation using thermic infrared sensors (TIR) to determine hydric stress in the orchard (Best et al., 2011). Both use Internet to broadcast weather conditions in real time.

Box III.12
Irriga System, Brazil

Sistema Irriga was launched in 1993 at the Federal University of Santa Maria, Brazil. The project is currently available to private enterprises and rural producers in 8 Brazilian States and in others countries like Uruguay and Mexico. Currently the system monitors annually more than 50.000 hectares.

The main purpose is to make available to irrigating farmers a practical irrigation handling system, functional and friendly; it also helps maximize the efficiency in water use in irrigated areas and minimize environmental impacts. Irriga provides information on when to irrigate and the water use rate for different production systems, making irrigation a more efficient process and reducing excessive irrigation and the harmful consequences of it (for instance, loss of nutrients by percolation under the root region).

The general system has a Platforms of Collected Data (PCDs), which collects information from the weather platforms in real time, and the register of cultures, soils and equipments. All these parameters serve to make the irrigations recommendations such as minimum and maximum blade of irrigation or a minimum time of blade application. The system also offers the possibility of technical assistance to train people on the field.

Stakeholders can access their personal account on Internet to consult the irrigation rate according to environmental conditions, like weather conditions (air temperature, precipitation, wind velocity and direction, relative humidity, global solar radiation, atmospheric pressure), soils and culture type and irrigation equipment. They can access their account with daily or predictive information (24-48 hours).

Source: http://www.sistemairriga.com.br/index.php.

The Integrated Water Resources Information Systems (IWRIS) illustrate another area of potential use of ICTs in irrigation. ICTs are used in these systems to generate and deliver basic and processed information related to weather conditions and irrigation efficiency: temperature, humidity, wind speed, solar radiation, rainfall, evapotranspiration, etc. Based on this information farmers can thus take decisions about times and frequencies of irrigation. Originally developed in California[70] this methodology has also been implemented in LAC countries. In Chile, for instance, the system has led to water savings of 30% to 60% in drip irrigation as well as energy savings due to a more efficient use of water pumps and improvements in the quality of crops.[71] An additional advantage of IWRISs is their integrated management of irrigation and fertilization tasks, known as fertirrigation, leading to a higher efficiency compared to traditional systems in the use of both water and nutrients.

c. Potential and current challenges

One of the major challenges agriculture (and human society in general) faces is how to produce enough food reducing at the same time the impact on the environment due to inappropriate water management practices. New technologies for irrigation and wastewater treatment are needed to overcome this challenge. PI has a potentially positive impact on both agricultural productivity (allowing to increase food production) and water use efficiency (allowing to decrease water withdrawals and agriculture's environmental impact). A systemic approach that integrates irrigation systems, crop models and weather risk management is a step forward in supporting farm decisions regarding water use.

Software systems like AquaCrop offer the potential for LA farmers to use water more efficiently and increase crop yields. Nonetheless, small-scale farmers in Latin America often have limited access to a computer or the Internet. Access to the required equipment, as well as training, are the main obstacles to the adoption of ICT systems for water management in the region.

3. Pest and weed control

Pest and weed control is another important area of potential ICT applications in agriculture. Based on summarized agronomical knowledge, like host-pathogen or pest and environmental conditions, the control arises from epidemiological models and weather conditions monitoring. Integrated pest management (IPM) with precision agriculture practices is seen by many researchers as a way to control pest and weed infestations

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70 www.water.ca.gov/iwris.

71 www.citrautalca.cl.

while also preserving the environment. Indeed, PA can help determine site and time-specific control needs in a more precise way and build prescription maps to support agricultural practices that are both effective against pathogens and safe for workers and the environment.

Early diagnosis of pests and weeds can be a powerful cost-saving tool for farmers. ICTs can play an important role by:

- Bringing experts together in virtual communities;
- Establishing monitoring and early warning systems;
- Extending effective monitoring and prevention techniques into more remote areas;
- Creating pest and weed prevention information systems.

The use of variable rate technology (VRT) in pest control demands the support of PA tools like prescription maps. These maps can translate into spatial forms the information required for decision making such as the characteristics of the crop (type, history, density, etc), the agrochemical (type, coverage, doses, etc.) and the levels of pest pressure, among others. Based on this kind of data producers can take decisions regarding the optimal rates of application of agrochemicals in specific areas, bringing economic and environmental benefits.

Over the years there have been many examples of rationalizing practices with site-specific and timely applications. Estimations of weed infestations can be made by conventional means or at real time (Dutra de Moraes et al, 2008). The conventional most common mean is to survey soil seed banks in order to estimate the composition and density of infestations (Shiratsuchi et al, 2003; Nordmeyer, 2006; Stahelin et al, 2009). Remote sensing and aerial photography integrated with GIS can also be used to identify weed areas. Estimations of weed infestation in real time are more complex; nowadays there are precise tools available for this aim but skilled users and technical support are usually needed to make a proper tool calibration (Gerhards & Christensen, 2003; Dutra de Moraes et al, 2008; Downey et al, 2010).

With the use of ICTs farmers are able to act in real time thanks to the immediate transmission of data from and to automatic agricultural machinery. VRT enables users to make changes in doses in real time following prescriptions or recommendations, both previously loaded into the monitors of a machine equipped with GPS or manually through an operator that already knows the variability of the park. Real time pest and weed control has increased with the wider use of PA, but the identification of the problem, the elaboration of prescription maps and the estimation of the economic threshold for agrochemical applications are still complex tasks.

a. Current situation in Latin America and the Caribbean

Basically every country in the region has developed some system to monitor the environmental conditions that favor the emergence of the most harmful agricultural pests and diseases. These systems have been mostly developed by the National Institutes for Agricultural Innovation (INIAs) and regional universities.

The major differences among the systems found in LAC countries rely on how they collect and model input data and how they disseminate the results of the model, affecting their impact on farmers' decision-making. For instance, input data can be collected with or without farmers' direct participation; modeling can use only numeric variables or incorporate geographic indicators and mapping based on GPS and GIS; and results can be uploaded on websites or directly reach farmers through short text messages. All these options have been found in LAC pest and weed control systems. Some of them are summarized in the next section.

b. Relevant experiences

The Brazilian Disease and Pest Information System (SID) was started in 2005 with a particular focus on monitoring Asian soybean rust. Today its main objective is to generate and transmit information on diseases and pests in soybean, corn and wheat. SID also has a warning system that closely monitors weather conditions that might be conducive to pest and disease infestations, allowing producers to effectively apply appropriate fungicides and pesticides (IICA, 2007).

In Argentina, Agrositio[72] provides information about crop diseases or attacks by insects. In Chile, pest infestations have been successfully detected using technologies that include near-infrared and thermal cameras that spot changes in temperature that may lead to problems with

72 www.agrositio.com.

insects (FIA, 2008). Satellite images are also used to analyze and detect potential outbreaks. Other relevant experiences in Argentina are presented on boxes III.13 and III.14.

Box III.13
FruTIC Project, Argentina

The aim of the FruTIC Project was to develop an integrated pest risk management system for the citriculture sector. This entailed to implement a network for production, transmission, transfer, processing and dissemination of environmental information (weather, soil and biotic community), phenology information and the main pest and diseases. ICTs are used to create an alert system of the environmental conditions that influence the occurrence of pests in citrus production.

The project covers an area of 55.893 ha close to the Uruguay River in the north of Argentina, where mobile phones and Internet are widely used. Stakeholders receive messages via e-mail or the mobile phone when the conditions are favorable for agricultural practices, because of meteorological conditions (i.e. frosts) and the presence of pests over the established limit. This allows taking productive decisions in a timely way and with proper support information.

The system is fed with data from different sources. Weather data are sent to the server in an automated or semi-automated way while trained people manually relieve the phenology stages from the land every week. Besides the message service, producers can access information on weather forecasts and thermal accumulation updated every 72 hours.

The FruTIC Project also offers data on host-pest-environment parameters for the most common disease or pest, supporting integrated pest management (IPM) practices. The database includes variables on flowering and budding state in non-irrigated parcels, flowering and budding state in irrigated parcels, date of full-flowering by zone, year and variety, as well as comparative graphs of phenological stages by date, graphs of the phenological stages evolution, daily values of plagues and insects, population curves for insects and phytosanitary indicators, growth curves and maturation indicators of fruits. Finally, based on Pascale et al. (2006), the project offers information on the theoretical time of irrigation as well as the amount of water consumed.

Source: http://www.frutic.org.ar and Milera et al. (2009).

Box III.14
National Project of Carpocapsa, Argentina

The National Project of Carpocapsa, also in Argentina, is an example of how ICT have been used to enhance the environmental sustainability of agriculture at the regional level (Villareal et al, 2010 and interviews to the Director of the Program, Mr. Adolfo Garcia Barros). The intervention strategy is based on surveillance and phytosanitary alerts, phytosanitary control and validation and technology training.

The project has developed an Integrated Pest Management (IPM) system, which has allowed minimizing chemicals applications due to the implementation of sexual disruption in blocks, following a modeled calendar. Every practice is thus monitored and controlled. Training and mutual learning – regarding agricultural practices, monitoring practices, calibration of agricultural machinery and the proper application of agrochemicals – are the link between producers and technicians.

In 2009 the total area of the project was 29,317 ha with 1,939 producers, 88.5 % or them small or medium size. A financial subsidy, granted according to the production area (to benefit small producers), was available during the first years of the project. From the third year on, once financial support was over, most producers (90% of those with less than 50 ha and 99% of those with more than 50 ha) carried-out the project on their own.

The results of the project in the last three years reveal important economic, business and labor market impacts, such as an increase in productivity levels and in the creation of jobs. Indeed, total productivity has increased since the program started due to an important reduction in the percentage of damaged fruit by Carpocapsa. In the period 2006-2009 the production increased 71,713 tons. Business impacts are a result of the incrementing of earnings since producers started selling to the fresh fruit market instead of the processing industry. Finally, the number of jobs in the sector increased along of the years for example in 2008 the program created 932 new jobs in the sector.

Source: http://www.funbapa.org/carpocapsa.

c. Potential and Current Challenges

Benefits of the use of variable rate technology (VRT) in pest control include improved application efficiency and accuracy, avoided overlap application, improved environmental stewardship and decrease in crop damage from over-application, optimized operator efficiency and lower operator fatigue (Taylor et al., 2005; Fulton, 2009; Ramirez-Davila et al., 2005). Research has shown that the elaboration of georeferenced prescription weed maps supports a more rationalized use of agrochemicals, reducing costs and the environmental pollution while maximizing efficiency in weed control

(Stahelin et al., 2009). Also, environmental and economic benefits has been reported from a significant reduction in the use of herbicide, due to the use of site-specific weed control in winter cereals sampled every year over a five-year period (1999-2003) (Nordmeyer, 2006).

Even though VRT can be seen as an alternative for pest and weed control that generates a more rationalized use of inputs, the limitations for the use of this technology are associated with its high costs of implementation and training, as well as with the obstacles for a proper identification of weeds. The adoption of VRT requires not only a substantial financial investment in equipment, but also in the skills required to use and interpret the computer-generated data, a significant challenge for small farmers in LA. Other difficulties include the understanding of how agriculture and the environment jointly evolve, generating conditions favorable to the emergence of pests and weeds.

In general, there is a lack of efficient methodologies for weed and pest remote identification, and trained users are still required. Some sensors have been used to identify weeds in real time, but so far only in research projects or in local productions. Farmers might benefit from further advances in this topic, especially from the eventual development of more efficient spraying machines. More accurate sprayers can avoid areas (e.g. watercourses) where the application of agrochemicals can be harmful, improving the environmental sustainability of agricultural practices. Another important tool is the satellite guidance that avoids product overlap and accumulation, preserving the environment and people's health.

4. Agricultural management systems

Modern agricultural management is an information demanding activity, which requires large amounts of diversified and objective information on the structure of sown areas, state of agricultural land, vegetation, soil and climate, expected yields, market prices, economic costs and returns, etc (Kobets, 2005). Moreover, the effective management of agricultural businesses calls for the integration of all this information into multi-component systems capable of providing real-time data, recommendations for action and, in some cases, prescription plans for the operation of agricultural equipment. In the current ICT age, agricultural management systems tend to go beyond information management, including decision-making, operational and supervising tools.

Agricultural management systems can be classified according to the scope of their functions into information management systems, database management systems, modeling and decision support systems and technology-embedded systems (mechatronics). Table III.14, adapted from Albornoz (2006) shows the main characteristics of each system.

Table III.14
Functions of agricultural management systems and related ICTs

	Main functions	Related ICTs	Uses in agricultural management
Information management systems	Process planning and control, accounting, finance, resources management	Generic or specific management software, Intranet, Internet	Resources and market planning, processes optimization, logistics, quality control, regulation fulfillment
Database management systems	Data collection, organization, management and dissemination	Satellite and aerial imagery, microscopic imagery, GIS/GPS, database management software, programming languages and platforms	Crop growth monitoring, yield forecast, biotechnology, genetic manipulation,
Modeling and decision support systems	Output and impact prediction modeling, decision support	Mathematical and physic/biological simulation models	Weather forecasts, sowing, fertilization, irrigation, equipment design, investment returns, assessment of agroecological impacts
Technology-embedded systems	Embedded data collection and interpretation tools, remote equipment control, automation of tasks	Embedded software, intelligent machines, robots, remote monitoring and control	Precision agriculture, precision irrigation, automation of agricultural tasks, real-time decision making

Source: Prepared by authors based on Albornoz (2006) and Kobets (2005).

The management of agriculture, like any other economic activity, aims to reach one or more of the following goals: optimization of economic costs, profits and benefits; production of defined levels of product quality and quantity; meeting timelines and schedules; delivery of value-added products and product attributes; attaining acceptable process reliability; maximization of efficiencies; realization of environmental and regulatory guidelines; optimization of human factors (safety, job satisfaction, performance, etc.) (Peart, 2004).

Probably the most challenging task in agricultural systems management is to deal with the uncertainty inherent to natural processes. Agriculture is decisively affected by unpredictable weather events as well as by the complex evolution of bioecological systems; its outputs are thus not completely manageable and controlled. Another important challenge in agricultural systems is to manage a value chain with multiple, highly unequal actors, especially in the primary sector. Product quality in the food sector is increasingly about accomplishing standards and regulations, but attaining this goal can be difficult when agricultural producers are too asymmetrical, dispersed or not coordinated.

ICTs improve efficiency in the management of agricultural systems in many ways. On the one hand, data collection, organization, modeling and communication have been clearly benefited by the introduction of ICTs. Specialized farm management software can track animal and crop information, map fields, simulate crop development, project harvest dates, create market forecasts, simulate the effects of best management practices, maintain financial and administrative records and help with a multitude of other tasks. As results, value-chain coordination has become more straightforward and effective; enforcement and performance evaluation mechanisms have been enhanced by more clear-cut indicators and output estimations have been facilitated by new simulation possibilities.

On the other hand, ICTs have promoted a new wave of automation and mobility of agricultural tasks and decision-making. Remote monitoring and control of sowing, harvesting and irrigation duties are now possible thanks to the use of radio controlled sensors, actuators, GPS, GIS and smartphones. The use of these ICTs in agricultural control applications is now feasible due to their decreasing costs. Agricultural systems managers have now access not only to more integrated data and more robust prediction models but also to tools that allow them to take decisions in real-time, wherever they are.

a. Current situation in Latin America and the Caribbean

Latin American agriculture is highly heterogeneous: commercial farms account for more than 80% of the production value in most countries while family farmers are the great majority in number. Management practices also vary greatly among the different farmers' categories. In most countries advanced management systems and the use of dedicated software and decision-making tools are highly disseminated among commercial farmers, especially in market-oriented value chains, but can be hardly found among family farmers. Optimization of processes, product quality and environmental regulations can be central issues for commercial farmers, but hardly the main goals of subsistence agriculture. Moreover, the use of management systems depends on the accumulated technologies and capabilities of each farmer, which influence the low response of small farmers to the new possibilities opened by these ICTs.

The low use of ICTs in small farms is also a limitation for the dissemination of modern agricultural management practices. In Brazil and Chile, for instance, data from Agricultural Censuses show that the penetration of computers, which is a basic tool in keeping administrative records and planning the use of resources, is ten times higher in the category of biggest farmers (over 500 ha) than among farmers with less than 5 ha. There has been, however, some effort from public policies to bring agricultural management systems closer to small rural farmers. Some relevant experiences in this sense are presented in the next section.

b. Relevant experiences

In Chile, the creation of Management Centers (CEGEs) supported by public funds and agencies is one of the most important attempts to make agricultural management systems more accessible to small farmers. CEGEs were created in 1995 and nowadays there are twelve centers distributed all over the country. Every CEGE delivers finance, tax and legal services to commercial and small farmers, according to their development level. The services include the collection and organization of finance information, performance control, strategic and commercial planning, tax accounting and legal support, among other areas. There is also a Network of Management Centers (GESChile)[73], which groups and coordinates the different CEGEs and also delivers additional services such as economic feasibility reports, update newsletters and dedicated software, systems and platforms for agricultural management. In the case of small farmers, the access to CEGEs services is mostly sponsored (80% of the total cost) by the Agricultural Development Institute of Chile (INDAP).

73 http://www.cegeschile.cl/inicio.

In Brazil, the National Agricultural Research Institute – Embrapa – supports the development and sharing of free software for agricultural management, which is another way of making these technologies more accessible to small farmers (see box III.15). Emater-DF, another Brazilian government agency, developed RuralPro, a software application designed to help small farmers manage their farms. As part of an agreement with IICA, Emater-DF will develop a version of RuralPro in Spanish and make it available free of charge to other Latin American countries, starting with Argentina, Paraguay and Uruguay. Emater-DF also plans to train instructors to teach small farmers in neighboring countries how to use this software.

Box III.15
AgroLivre: Free software for information management and decision-making in agriculture

AgroLivre is a free software network created and maintained by Embrapa Informática, the informatics division of the Brazilian Agricultural Research Institute – Embrapa. Embrapec and OpenFarm are two softwares currently available at AgroLivre.

The first is an analytical tool for assessing the current and expected economic performance of livestock enterprises. It was developed jointly by the informatics and the livestock divisions of Embrapa. Based on 370 variables classified into five categories (farm structure, strategic plan, performance indicators, feeding options and prices, costs and taxes), Embrapec generates reports to support the economic decision-making of farmers. The system also simulates the economic impact of strategic decisions concerning the expansion of the farm, the herd and the staff. It runs on a multiple, open-source software based platform.

OpenFarm is an accounting information system for farmers. It includes several receivable and payable accounts as well as an analytical module to assess crop yields on a month or year base. The reports generated by OpenFarm support farmers' decisions in areas such as products sale, inputs acquisition, and investment.

Embrapec and OpenFarm can be accessed on the following link: http://repositorio.agrolivre.gov.br

Source: Embrapa Informática Agropecuária.

A relatively new work area is the articulation of actors in value chains through the use of Enterprise Resource Planning (ERP) systems. Many food processing companies are now using remote systems to manage supply chains, that is, to coordinate services such as the delivery of products and the payment of suppliers. ERP systems allow farmers to easily follow (via the Internet or mobile phones) the quality and content analysis that their products must fulfill once they enter the processing industry and also estimate the final price that they will be paid. Most ERP systems also deliver weather and market information to farmers. To processing companies ERP systems allow the integration of all information related to their business (from input purchases to final sales, including stocks, accountability, resources use, etc.). Examples of ERP systems in use in agrifood chains in LAC countries include the SIAGRIWEB developed by the sugar company IANSA in Chile and the system operated by *Compañía Argentina de Granos* (CAGSA) in Argentina. Finally, it is important to mention that ERP systems can also be used to improve management in public organizations.

c. Potential and current challenges

Even small farmers can now cost-effectively attain greater efficiencies in the administrative functions of their operations by using farm management applications. Nurturing the development of home-grown technology suppliers could provide LA farmers greater opportunities to increase productivity and compete more effectively in regional and international markets.

Small-scale farmers in Latin America often have limited access to a computer or the Internet constraining their ability to use software that could help them manage their farms. As for many other ICT based technologies, access to the required equipment, as well as training, are the main obstacles to the adoption of ICT systems for agricultural management. Deeply-rooted attitudes also play an important role. Even with the necessary equipment, adoption of new technologies can be a slow process for farmers used to running their farms with pencil and paper.

F. Conclusions

The use of ICTs in LA agriculture is growing rapidly, with a broad range of technologies in use; however, their use is highly uneven in terms of technologies, types of farmers, and location. As with the adoption and diffusion of ICTs, the level and sophistication of public policies and programs supporting ICTs in agriculture also vary greatly across LAC.

Some ICT applications, such as precision agriculture and traceability, require the use of fairly costly and sophisticated technologies and users with the requisite technical skills, but many more farmers and agricultural organizations are making use of basic technologies that are easier to handle, like websites for information sharing, e-mail and mobile telephony. These latter technologies, categorized as systemic impact technologies in this chapter, have great potential but limited direct impacts on farm efficiency and productivity.

While the third order effects of the systemic impact technologies are primarily indirect and not easily measurable and quantifiable in terms of their impacts on agricultural productivity, they also generate much broader benefits. Virtual communities are playing a very important part in the process of sharing and learning. New biodiversity monitoring capabilities provide tools to help maintain the healthy ecosystems critical to a productive, sustainable agriculture, but the information gathered also serves much wider environmental purposes. Additionally, they provide the means by which many more people, including farmers and concerned citizens, can contribute to critical data collection efforts. Such initiatives also have an educative value and promote public engagement in environmental protection.

The development of new, more sophisticated early warning systems can benefit farmers directly by reducing losses from pests, diseases and weather events, but these technologies have even broader and more significant applications for protecting life and property. The same is true for traceability systems that, while ensuring export market access, enhancing the ability to respond to a variety of consumer demands and creating niche market opportunities for LA producers, are also a critically important tool for protecting public health.

The economic impacts of enabling technologies can be more easily measured. While these technologies do not contribute directly to agricultural productivity, their second order effects can extend quantifiable financial benefits to actors in all segments of the value chain. Branchless banking and e-commerce are important new tools that can reduce transaction costs, lower input costs by increasing price competitiveness, improve access to existing markets and create new market opportunities.

Even though the diffusion of internet access is still limited, mobile telephony is a more widely available core platform that allows the use of these enabling technologies, especially for their adoption and diffusion in rural areas. For farmers, mobile telephony is a reliable and timely communication channel for access to new markets, extension services, monitoring and alert systems and new financial services. It offers multiple formats for information in one device, provides accessibility for illiterate users (i.e. voice and images) and facilitates quick communication for time-sensitive information (e-agriculture, 2009).

First order effects are measurable and quantifiable in terms of their direct impacts on agricultural productivity. The examples discussed here –precision agriculture, precision irrigation, pest and weed control and agricultural systems management– provide means to allocate farm resources more efficiently and effectively to increase yields and reduce potential losses. As is the case with the beneficial environmental side effects of the application of PA tools, they can also have important spillover effects. However, the adoption, implementation and diffusion of these technologies are constrained by their cost and the need for users to have a high level of technological literacy and skills. They are less applicable to smallholdings and at present still offer a limited potential of diffusion among small rural producers.

It is important to remember, however, that small farmers with less sophisticated skills and without access to costly technologies often use the same PA principles in managing their farms. Then, more knowledge is needed on the extent that aspects of precision agriculture and other direct impact technologies can be applied to smaller operations, notwithstanding the constraints. The argument put forward by Blackmore (2007) about the possibility of a "softer" version of precision agriculture, better adapted to developing countries, is highly relevant in this context. It is possible to imagine less sophisticated models, better adapted to the characteristics of LAC agriculture.

From a policy perspective, the classification system for ICTs presented in this chapter have showed that even generic ICT uses such as virtual communities and electronic trade systems are important for agriculture competitiveness and should not be excluded from a integrated, systemic view of agricultural policies. Public policies that are not specific to agriculture will thus play a critical role in the evolution and growth of the sector.

This requires an effort of governments towards a better articulation of different ministries and strategic areas (telecommunications, infrastructure, finance, trade, etc.) with the agricultural institutions to promote policies that are wide and inclusive enough while still considering agricultural particularities and needs. Cooperative regional efforts have an important part to play in supporting this articulation, for instance, promoting political dialogue among partners, disseminating best practices and inducing the participation of the different economic sectors, including agriculture, in the discussion and implementation of national digital agendas.

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IV. ICTs and information management (IM) in commercial agriculture: contributions from an evolutionary approach

Graciela E. Gutman and Verónica Robert

A. Introduction

The central aim of this chapter is to present a preliminary outlook on the applications of information and communication technologies (ICTs) in the agricultural sector in Latin America (LA) and their impact on farmers' information management (IM). The chapter focuses its analysis on the assessment of impacts on learning processes related to data and information accumulation, organization and dissemination. It also considers how these technologies modify, or could potentially transform, the way farmers organize and manage their production and marketing processes. Agriculture is considered in a broad sense —farmers, agricultural producers and other organizations involved in these activities— as part of agro-industrial systems or sub-systems which include product and service suppliers, processing industries, distribution and marketing services, as well as the regulatory, institutional and competitive environment.

This analysis of ICTs and agriculture stems from a historical overview of the evolution of agriculture and the successive waves of technological revolutions that have occurred in the last century. It combines two theoretical frameworks: (i) structuralism, which provides adequate tools for understanding the limits to a full industrialization of the production process in agriculture; and (ii) the contributions of the evolutionary theory of innovation in relation to the forms of ICT diffusion (drivers and impacts) and the associated learning processes. Both theoretical frameworks are analyzed within a systemic perspective that takes into account the interactions between innovation networks and the productive and technological dynamics related to value chains.

ICT diffusion can be analyzed in different ways: a *demand-side perspective* (the information-dependent nature of farming and related decisions); a *supply-side perspective* (the technical and organizational aspects of providing access to ICT-based services in rural areas across the agricultural supply chain); and the *technical aspects* (connectivity, computers and peripherals, software and applications, and the capacity building of farmers and other users in rural areas) (Rao, 2006). Our analysis is focused on the first two approaches.

This chapter is largely based on an extensive literature review of the new trends in the use of ICTs in commercial agriculture in LA. However, the available literature pays little attention to the analysis of the impacts of ICT diffusion in agriculture. The literature review is complemented with a series of interviews with experts, researchers and technicians from public and private institutions, technology suppliers and technical advisors, and some agricultural producers.

Several questions have guided this study:

- Are farmers and agricultural producers the main recipients of ICT diffusion or are these tools used primarily by others actors in the value chain, mainly service and input suppliers?
- What is the role of agricultural producers in the technology transfer process and how do they interact with other players?
- What are the drivers and transfer mechanisms in this process?

The central thesis of this chapter is that in the modern productive and technological context of LAC agriculture the diffusion of ICTs impacts mainly on the information management (IM) of the farm. ICTs work as enabling technologies, improving the possibilities for gathering, processing and transferring information. ICTs do not represent by themselves codified scientific or technological knowledge which demand the application of tacit abilities to be useful; neither do they enhance the farmer's knowledge capabilities. Rather, ICTs accelerate the farmer's learning and management processes because they give access to a set of specific techniques for the management and recombination of information.

The analysis is focused on commercial farms, where ICTs currently have a larger degree of diffusion. This focus considerably reduces the field of observation. The vast majority of rural producers, who do not yet have access to these technologies, fall outside of the scope of this analysis.

B. Innovation and technological change in agriculture: some conceptual issues

Agricultural production has specificities associated with its natural bases that influence both its productive dynamics and its technological trajectories. In different stages of capitalist production, these constraints were overcome by specific innovations and technological changes. In this section, after addressing some relevant conceptual issues, we will discuss those aspects and develop an analytical framework based on these specificities, taking into account the contributions of the evolutionary approach.

1. ICTs and information management in agriculture

Modern ICTs have transformed the way data is processed, stored, transmitted, managed and used. The widening scope and greater availability of information and the enhanced capacity to process it have induced substantial changes in the way the production and circulation of goods can be managed, as well as in the ways in which scientific and technological knowledge can be transmitted and transferred.

Several authors (Boisot and Canals, 2004; Jonhson, Lorenz and Lundvall, 2000; Malerba and Orsenigo, 2000; Cowan, David and Foray, 2000; Hovland, 2003) note that data and information are usually taken as synonyms. Information is also often equated with technological knowledge. This is a consequence of a lack of precision in the definition of information, especially when knowledge is considered as an economic good, when there are costs associated with access, and when information is simultaneously an input and an output in the production of new knowledge (Antonelli, 2011). For Hovland (2003), raw information may be widely available to a number of agencies, but only some organizations will be able to convert the information into relevant knowledge and to use this knowledge to achieve their aims. Wilson T.D (2002) argues that data, information and information resources may be managed, but knowledge (i.e., what we know) can never be managed except by the individual knower and, even then, only imperfectly.

A number of authors believe it is important to differentiate between tacit and codified knowledge[74]. Codified technological knowledge is viewed as a public good with symmetric access for all economic actors. This vision contrasts with the more complex and rich conceptualization developed in the last three decades in the evolutionary approach to economic change related to industrial innovation processes (Nelson and Winter, 1982; Dosi, Nelson and Winter, 2000; Johnson, Lorenz and Lundvall, 2000; Malerba and Orsenigo, 2000; Cowan, David and Foray, 2000; Ancori, Bureth and Cohendet, 2000). These authors argue that it is important to distinguish between tacit and codified knowledge, and between internal and external sources of learning and the development of new organizational competencies. These distinctions are necessary to understand the specificities of scientific and technological knowledge as economic goods and as essential facilities for knowledge generation (Antonelli, 2007) and the specificities of the transfer processes.

Tacit knowledge imposes limits on the diffusion of technological knowledge, in addition to those imposed by institutional barriers such as intellectual property rights. The importance of knowledge related to local characteristics and conditions and the asymmetric relations between firms influence the ways in which data, information and knowledge are diffused. Technical assistance agreements reshape the spaces for cooperation and competition.

The evolutionary approach points out that the efforts of firms and organizations in the search for data and information are related to their previous capabilities. Unrestricted access to information, if that is possible,

[74] Since Nelson and Winter (1982), and taking into account Polanyi's works (1958, 1967), literature on (technological) knowledge, learning processes and innovation has distinguished between tacit and codified dimensions of knowledge. Codified knowledge refers to pieces of knowledge which are available in the form of handbooks, patents, blueprints and so on. This knowledge is easy to diffuse and transmit because the primary barrier to its diffusion is a lack of pre-existing skills that enable the reading and interpretations of the codes. Tacit knowledge is knowledge that cannot be articulated; the set of skills that allows a person to perform an activity although that person is not able to describe or articulate each action involved in the activity. In Polanyi's words "We know more than we can tell." (1967:4).

does not imply equal opportunities for the generation of new knowledge. These inequalities result from the differing internal and external capabilities of individual firms and are conditioned by the presence of asymmetries in industrial structures. In this context, the learning process is accumulative and path dependent, resulting in non-linear dynamics and self-reinforcing processes which over time reproduce the initial differences in the technological capabilities of firms. In addition, firms have different capabilities for taking advantage of the economic benefits related to new knowledge, which in turn increase the asymmetries and hierarchies among firms and strengthen the uneven diffusion of technological knowledge.

The effects of these differences are even more pronounced because of the fragmentation and enclosure of knowledge through the patent system and when there is significant heterogeneity between firms and producers. These features have dissimilar impacts on different productive sectors depending on their economic structure and regulatory environment (Dosi, Marengo and Pascualli, 2006).

The development of new technological knowledge is the result of a systemic process in which internal and external learning sources converge, resulting in new knowledge, both tacit and codified, and differing in type: *know why* —scientific knowledge; *know how* and *know what*— operative knowledge (the former based on experience and the latter on codified knowledge); and *know who* —knowledge associated with the search for the right partners for different tasks. This convergence occurs in networks connecting the conceptual elements distributed in the theoretical academic space (universities, institutions, technological centers, firms) with the practical knowledge and information acquired in the productive space.

The evolutionary approach to technological knowledge, learning processes and technical trajectories has been primarily applied to the innovation processes in the industrial sector. To extend this approach to the agricultural sector it is necessary to adapt the conceptual tools to the specificities of agricultural production and to the particular ways that the generation, acquisition and diffusion of tacit and codified knowledge take place in agriculture. We deal with these issues below and will turn to the evolutionary concepts in section C.

2. Modern agricultural production

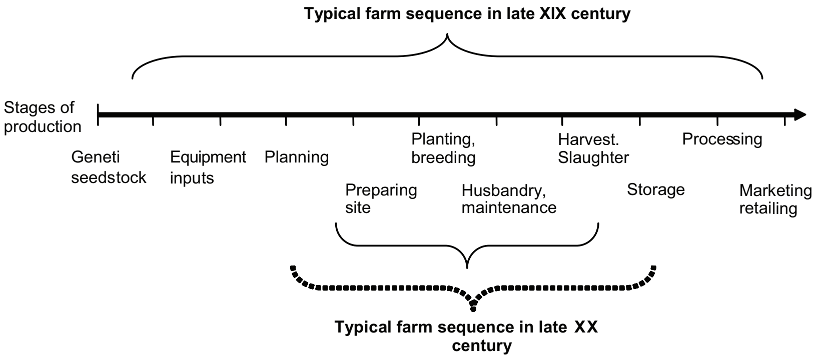
What are the main traits of the modern commercial agricultural production related to technological change and, more specifically, to ICTs and information management? To begin, we will outline the relevant specificities of agricultural production, their historical evolution and the characteristics of the technological revolutions that have reshaped agriculture over time.

a. Historical evolution

Modern agriculture differs dramatically from agriculture as practiced at the end of the nineteenth century. At that time, when the productivity of labor and land was relatively low, the farmer was the main actor responsible for the organization of production and the development of new techniques. Today, agricultural production is the outcome of the interrelated and interdependent actions of a variety of players from different economic sectors in a very different institutional and regulatory environment, oriented to both domestic and international markets. This historical transformation occurred as a result of the increasing division of rural labor driven by technological change, with the consequent outsourcing of activities and processes and the growing differentiation of farmers and their productive and technological capabilities. Inputs, machinery and rural tools are now provided by industrial firms; post-harvest activities have become specific tasks performed by new agents; industries processing raw agricultural inputs have gained importance; and new technical services suppliers have emerged. These changes have resulted in huge increases in productivity and a progressive weakening of the farmer's technological skills and capabilities.

The description of the evolution of family farms in the USA since the end of the nineteenth century, illustrated by Allen and Lueck (2000), depicts a process that has also occurred in Latin America (see figure IV.1).

Figure IV.1
The operational extent of the US farm in the XIX and XX centuries



Source: Allen D. and Lueck D. (2000).

Today, as shown in figure IV.1, farm activities are generally limited to planting and breeding, site preparation, husbandry and maintenance and, less frequently, harvest or slaughter. On large commercial farms, particularly in extensive grain and oilseed operations (as in the Argentinean Pampas) sowing, harvesting and pest control activities have been increasingly externalized and are often carried out by contractors.

This process has led to an increasing integration of agriculture production into the dynamics of the industrial, commercial and financial sectors, with different and complex coordination structures. As a result, industrial inputs account for a growing share of agricultural costs. Farmers have progressively experienced the loss of their productive and technological autonomy, in parallel with the emergence of new asymmetries and structural heterogeneities.

The historical evolution of agriculture has changed the nature of the rural farm as an organization with delimited boundaries and as an autonomous decision unit. As a result, the analysis of the productive and technological evolution of this sector requires a systemic approach, taking into account the interdependencies and interactions among players and sectors and the asymmetries that have emerged among them (Gutman 1991, 1999, 2003; Gutman and Gorenstein 2003; Goodman, Sorj, Wilkinson, 1987; Allen and Lueck, 2000). For this purpose, we consider two different, but complementary, perspectives in this systemic approach: a network perspective and a global value chain (or subsystem) perspective.

The diffusion of ICTs and, in general, of new technologies in the modern commercial agriculture occurs within networks. At the same time, agricultural producers are integrated into agro-food systems by means of vertical coordination and formal or informal contracts. Governance and coordination of the technological and commercial processes of agricultural production are mostly concentrated in companies and organizations located in other segments of the chain (input suppliers, industrial processors and wholesale and retail distributors). This has been called by some authors the "modern agricultural technology system", defined as a multidimensional network of public and private organizations interacting non-linearly in a given historic context. This system embraces all of the innovative processes that take place in this sector and its value chains.

Four main drivers are responsible for contemporary changes in agriculture: (i) the increasing globalization of production, markets and business strategies; (ii) new regulatory and competitive environments in regional, national and international markets and the intensification of global competition; (iii) continuous waves of technological change; and (iv) changes in consumption patterns and increasing consumer demands and regulatory requirements related to food quality and safety, convenience, choice and the reliability of supplies.

As a consequence, we have seen drastic restructuring and differentiating processes in agro-industrial systems: vertical integration and new contractual relationships between producers, processors and input suppliers, coupled with a reduction in the number of agricultural producers and a rise in average farm size (Gutman, 2003).[75] Technology, organizations and institutions have coevolved. The central features of this process are the de-commoditization of agricultural production, the concentration and centralization of capital in the industrial and commercial stages, the growing power of multinational enterprises (MNE) and the emergence of new strategic actors and methods of control and governance in value chains (Langlois, 2003).

75 There has been a dramatic consolidation in the global commercial seed and agrochemical industries over the past 40 years. Since the commercialization of GM crops in the mid-1990s, three large multinational pharmaceutical and chemical corporations —Monsanto, DuPont, and Syngenta— have gained control of the seed market through the acquisition of numerous small companies and mergers with large competitors. It is estimated that the four top pesticide firms control almost 60% of the global market and the top four seed firms control 56% of the global proprietary seed market (Howard, 2009).

Over the course of this historical process, the intensity and nature of the changes in technology and production techniques in agriculture have been increasingly determined by the organizational, technological and competitive dynamics of industrial, commercial and financial firms operating in other stages of the agro-industrial system.

b. Technological revolutions in modern agriculture

The biological characteristics of agricultural production greatly differentiate farm organization from industrial organization:

1. Agriculture involves a living, growing product which goes through several distinct stages largely determined by nature. Seasonality is the main feature that constrains the industrialization of agriculture.[76] In other words, the technical division of labor is limited. In economic terms, it means that production processes are longer than labor activities, which results in a greater immobilization of capital and, consequently, a lower rate of capital rotation.
2. Natural random forces affect production, introducing uncertainty,vsuch as pests, diseases and weather events.
3. Continuity and homogeneity in agricultural production are affected by geographic dispersion, access constraints and the limited quantity and variable quality of land.

Technological developments and innovations have historically been employed to try and overcome these natural restrictions: genetics, fertilizers, new varieties of crops, agrochemicals for pest and disease control, mechanization and agronomic techniques to reduce labor needs (consequently raising the rate of capital rotation), irrigation systems, green houses, land conservation practices and the creation of "new land" with the expansion of the agricultural frontier through logistic and transport innovations[77]. In general terms, mechanical innovations affect the intensity and length of the working day; chemical innovations modify the natural conditions of soils; biological and biotechnological innovations aim to

76 "Industrialization" is defined here as the process that involves, among other important factors, the maximization of the technical division of labour, the reproduction of productive units without natural limitations and a permanent reduction in the rate of capital rotation.

77 The modern livestock industry differs in important aspects from other agricultural activities because new technologies —confinement facilities, disease control, genetics, nutrition, transportation— have greatly reduced the effects of seasonality (Allen and Lueck, 2000).

reduce the impacts associated with the seasonality of production; and agronomic innovations provide organizational improvements to achieve production efficiencies (Graziano da Silva, 1991).

Traditionally, technical progress took place in agriculture through a trial and error process, based on on-farm experimentation, the selection and adaptation of local crops and, later, by crop hybridization through crossing varieties with desirable characteristics.

More recently, major restructuring processes and new technological paradigms have brought about significant changes in agricultural production. During the second half of the twentieth century, two important technological revolutions transformed Latin American agriculture —the Green Revolution and the modern biotechnology or Gene Revolution (Parajil, 2003 and Gutman and Lavarello, 2007).

The development, adoption and diffusion of information and communication technologies —a new paradigm that has deeply transformed organizational and innovation processes in other economic sectors— raises important questions related to their impact on agriculture.

Assuming as an initial hypothesis that in ICTs we are witnessing a third revolution in modern agriculture, it is important to point out that the development and diffusion processes, the associated learning processes and intellectual property protection followed different trajectories in these three technological revolutions, resulting in different innovation systems.

The Green Revolution, which began in the 1960s, resulted from the development of high-yielding seed varieties, primarily of rice and wheat, and the adoption of a package of modern agricultural tools and practices including chemical fertilizers, pesticides, improved irrigation systems and techniques, and tractors and other farm equipment. Agricultural research, supported initially by a network of national and international organizations, was largely conducted by public bodies (INTA, INIAs), which were responsible for technology transfer and training activities. With the privatization of technological knowledge, MNEs played a much larger role, mainly in the agrochemical segment of the value chain.

The modern biotechnology and ICT revolutions in agriculture, beginning in the 1980s and 1990s opened new technological trajectories with significant changes in the structure of research and the roles and hierarchies of the firms and actors involved. Notwithstanding their specificities, they share among other traits, a strong interplay between basic science and technology, the nature of their roles as enabling technologies, their generic and transversal character, as well as their convergences and synergies with each other.

The application of modern biotechnology in agriculture has vastly expanded the commercial opportunities for agricultural research (genetic engineering, molecular markets and so on). Since the 1980s, large multinational firms have invested in R&D to create transgenic crops with special traits: pest and agrochemical resistance, drought resistance, and specialized characteristics for industrial processing. These scientific and technological advances have acted as a powerful knowledge base for innovation and technology development. Private actors played a leading role in the innovation and diffusion of agricultural biotechnology related to the genetic revolution (Gutman and Lavarello 2007, Salles-Filho, 2007 and Schimmelpfennig and King, 2004).

ICTs have had an enormous impact on economic activities, including agriculture, with the diffusion of generic and specific tools. Their importance in agriculture is largely due to their role as facilitators and drivers in the diffusion of other techniques and technologies in the sector. While generic ICTs shorten distances and drastically reduce communication and transaction costs affected by the geographic dispersion of production, specific tools are focused on (i) further codification and systematization of information on soil characteristics, climate, diseases and pests, with the aim of optimizing the use of inputs and the consequent cost savings and yield increases (mainly precision agriculture tools, public-private systems for agricultural information and early warning systems); and (ii) creating and implementing product identification and traceability systems to document origin, address issues related to food quality and safety and to develop new markets based on product differentiation.

The diffusion of these transformative technologies in agriculture has differed. While the green revolution has affected the whole spectrum of agricultural production, modern biotechnology and ICTs are still concentrated in certain crops and certain types of agricultural operations. However, due to their pervasive nature, the potential for ICT diffusion to a greater number of farmers is high, particularly for generic applications.

The main features of these modern technological revolutions are presented in table IV.1.

To sum up, the modern productive and technological dynamics of agriculture are characterized by two main trends. On the one hand, by an increasingly complex systemic dynamic where industrial, commercial and financial firms play a central role, setting the direction and speed of the technical changes in agriculture and, on the other hand, by the movement away from rural producers as the generators of technological knowledge in agricultural production. Indeed, the historical know how of farmers, based on experience and trial and error processes, has been mostly externalized and re-introduced in the productive processes as inputs or technological services offered by other firms and specialized suppliers. Large multinational enterprises (MNEs) functioning in highly concentrated markets, in technological alliances with other industrial firms, universities and public centers on science and technology, are the main producers of new knowledge.

Technological diffusion in agriculture takes place primarily by means of "technical packages", where technology is embedded in agricultural inputs, machines and software. New actors working in more or less closed networks are central players in the diffusion of new techniques and the related learning processes are, in most cases, addressed to technical advisers (agronomists, veterinarians, internal or external rural consultants), intelligent-machine operators and suppliers of specialized technological services.

C. ICTs and IM in Latin American commercial agriculture: a methodological proposal

In order to analyze the changes in information management in Latin American agriculture we propose a methodological approach that attempts to capture the specificities of the sector.

The current literature on ICTs in Latin American agriculture mainly addresses issues related to the impacts their diffusion has, or might have, on socio-economic factors (emphasizing the democratizing effects of access to information), the scope, variety and application of the techniques and tools associated with ICTs, the research and findings of different public institutions and the public policies and programs focused on understanding and overcoming the obstacles to ICT dissemination in rural areas AHCIET, 2010, Albornoz y Robert, 2008; Bossio et al, 2004, CENDEC- FIA 2008, IICA 2007, among others).

Less discussed are the direct economic impacts of ICTs, such as performance indicators, cost reduction, increased competitiveness and access to markets, and the ways technological transfer and the related learning processes take place. This is largely due to two reasons: the lack of appropriate indicators for this kind of analysis in the traditional surveys of the agricultural sector and, the methodological difficulties in isolating ICT impacts from those that result from the co-implementation of other important process and organizational innovations and technologies, as ICTs are largely facilitators in the dissemination and application of other techniques and technologies.

Taking into account these limitations, we propose two interrelated taxonomies considering, on the one hand, different categories of commercial agricultural operations and, on the other hand, the different learning processes associated with them, based on a systemic evolutionary approach. These taxonomies aim to capture the major trends in the impact of ICT diffusion on farmers' information management, taking into account the heterogeneity of Latin American agricultural production, both between and within countries, related to the relative size of farms, the ownership structure (for land and other means of production), different organizational structures, the types of interactions in value chains, the degree of development of commercial agriculture, the levels and forms of integration into world markets and access to technology and financing.

Regarding the interaction between the taxonomies, we analyze the expected impacts on information management associated with ICT diffusion. The outcome of this methodological exercise is thus compared with the experiences reported in a number of selected case studies. The main hypothesis is that ICT diffusion impacts are shaped by the previous capabilities of rural producers, by their experience with learning processes associated with previous technological changes, and, last but not least, by their position in the agro-industrial value chain.

Table IV.1
The green, gene and ICT revolutions in agriculture

Dimension	Green Revolution	Gene Revolution	ICT Revolution
Knowledge infrastructure	Public sector research (open science)	Intellectual property rights	Distributed Knowledge in the network. Major role of public agencies in promoting and training. Private control of technological change (machinery and specific software)
Network configuration	Large networks: national and international research institutions, bilateral and multilateral donor agencies, MNFs, farmers	Narrow networks: Private agrochemical, biotech and seed firms, DBF, research universities and S&T centers	Large networks: national and international public agencies, private firms, universities, service and technology suppliers and a new generation of farmers (entrepreneurial with high formal education)
Associated technologies (Technological packages)	High-yield hybrid seeds, agrochemicals, fertilizers and farm machinery	GM crops, herbicides (self fertiliz. seeds), farm machinery and new farm practices. Technological convergence	Internet, mobile telephony, GPS, GIS, PA, EWS, specialized software applications, high-tech farm equipment Technological convergence a/
Learning processes	Technological transfer and local adaptive work by public institutions	Privatization of the research infrastructure and technology transfer	Technological transfer and local and idiosyncratic learning
Techniques	Conventional methods of tissue culture, cell fusion, selection and cross breeding	rDNA, genome sequencing techniques, genetic engeering, molecular markers, direct manipulation of plants	Production: PA, irrigation, disease and pest control, early warning systems, etc. Management: data processing, administrative tools, e-commerce, traceability systems, etc.
Public and private roles	Key players: public institutions and agrochemical suppliers	High privatization and concentration of new knowledge. Relevant role of the institutional context and of complementary assets.	Significant participation by both sectors
Scope of diffusion	Widely diffused. High impact on agricultural production	Concentrated in a few crops with high impacts on costs and yields	Limited, ueven diffusion. Generic technologies more widely diffused. Specialized applications and machinery limited to large/medium-sized farms
Period	1960s-1980s	Started in the 90s	Varies by technology. For example, PA and electronic traceability, since 2000; generic devices (cell phones and internet), since 1990.

Source: Prepared by authors, on the basis of Parajil, (2003) and Gutman and Lavarello (2007).
[a] *We consider precision agriculture to be the most important technological innovation of this revolution.*

1. ICT diffusion and learning processes in a heterogeneous agriculture

Modern commercial agriculture is a knowledge and information intensive activity. Increasing competition in international markets, choosing the right inputs for achieving and maintaining market competitiveness and the rising risks of climatic fluctuations are some of the challenges that agricultural producers currently face. To manage farm production in this environment, farmers need to make critical decisions throughout the year based on the selection of inputs (seeds, water, fertilizers, and agrochemicals), the organization of the production process and the related market transactions. They also need to keep abreast of public policies, credit markets, regulatory and statutory requirements, prices and market changes[78]. ICTs are critical tools for addressing these needs.

In regards to ICTs in agriculture, some authors differentiate between the production of functional foods (staple goods with predictable demand) and innovative goods (differentiated niche products, short life cycles). The former are focused on increasing yields and reducing costs, the latter, on quality and customer loyalty. Their ICT requirements are different as are their supply chain management approaches, learning processes and transfer mechanisms (Salin, 1988).

In a systemic view (value chains and learning networks), the varying levels of ICT adoption in different segments of the chain – whether among firms in a particular segment, or between different types of chains – is an important consideration. A significant level of ICT adoption is found in some areas of the input and service supply segments and in retail food firms. For example, at the retail level, the point scanner is the key IT tool for tracking retail demand and gives retailers the opportunity for market leadership within the segment through their information advantages. At the other end of the value chain, bioinformatics has become a key tool in the development of new seeds and inputs (Gutman, 2002).

In short, in agro-industrial systems there are two stages in which ICTs and information management are of central importance (Sonka et al, 1999, Gutman and Lavarello, 2007): (i) biotechnology and GMO through the

[78] In Europe, quality assurance and traceability requirements are among the biggest drivers of ICT adoption in the agricultural sector (Gelb and Offer, 2010).

use of bioinformatics that makes it possible to more quickly and cheaply identify potentially valuable DNA sequences across huge data sets; and (ii) mass customization, i.e., products and services that are customized to meet specific client or consumer needs at a lower cost.

In between these two extremes, there is a wide range of information needs and ICT applications to address them. However, agricultural producers have different levels of access to these technologies and different adoption capacities that require learning processes and information management adapted to their conditions.

Taking into account the high level of structural heterogeneity in Latin American agriculture, technological changes and their impacts on the sector differ across countries. In Argentina, for instance, the emergence of contract service providers in some extensive commercial agricultural operations, coupled, since the nineties, with the expansion of financial investments in the sector (trusts, seed pools), has precipitated the emergence of distinctive organizational forms not found in the commercial agricultural segment of other countries in the region.

The proposed taxonomies aim to deal with this heterogeneity and shed light on the information management changes sparked by the diffusion of ICTs, taking into account the following questions:

1. Is the use of ICTs for data accumulation, organization and dissemination in the agricultural sector positively impacting learning processes and innovation? Which aspects of the production and innovation processes in agriculture could be enhanced by the adoption of ICTs?
2. What are the drivers for the adoption of ICTs?
3. Which firms or groups of firms are responsible for setting and coordinating the dissemination of new standards for processes and products associated with the adoption of ICTs and who is responsible for enforcement? Who manages the coordination and governance of the chain?
4. What are the specificities of the learning processes associated with ICTs? Who are they addressed to: producers, suppliers, facilitators, service providers or others?
5. Who is responsible for the transfer processes and what are the specific transfer mechanisms?

2. ICT diffusion among different types of commercial farmers in Latin America

In the wide body of literature dedicated to the analysis of the evolution of the agriculture sector in Latin America, there are a number of different typologies of farmers based on variables such as size, organization of production, type and destination of goods produced, level of integration in value chains, technological level, organization of labor and degree of mechanization, among others (see, for instance, Lodola, 2006; Leavy and Dewes 2009, Teubal 2002; Schejtman and Barsky, 2008; Gutman, 2007).

The taxonomy proposed in this study is focused on commercial farmers. It is intended to capture, at the regional level, the differential impacts of ICTs on the innovation and learning processes of farmers and should be considered an exploratory exercise based on previous research. For the construction of the typology we took into account the following factors: farm size, organizational structure, goods produced and market orientation.

Types of farms:

1. Large and medium-sized farms for extensive crops (mainly grain and oilseed production), primarily owner operated, but including some rented-land operations.
2. Agricultural management enterprises (AME) that manage their own farms and also provide financial, technological, logistical, marketing, and risk management services to other, smaller farms. This category includes large investor-owned farms, primarily in Argentina, engaged in the production of extensive crops like grains and oilseeds.
3. Medium-sized and small, export-oriented farms managed by owners or tenants (mostly fruits and vegetables)
4. Large and medium-sized and dairy farms
5. Cattle producers

Large farms of type 1 and 2 are linked upstream to suppliers of technological packages related mainly to modern biotechnology techniques and downstream to marketing and distribution firms or food companies. The main difference between these two kinds of farms in regards to ICT impacts is their planning horizon. In farms type 1, and particularly in medium-sized farms managed by the landowner, long-term strategies directed at the preservation of natural resources are more common. In these cases, learning processes for new technologies are important. In farms type 2, short-term financial strategies prevail and, consequently, there is a low level of interest in learning processes related to conservation strategies. However, AME may pursue hybrid strategies with strong learning processes for new technologies, coupled with short-term strategies for land conservation and reduced learning processes in client farms due to uncertainty with regard to the duration of their contracts. In these cases, the management firms may build up generic competencies and diffuse them throughout the network. For type 1 and 2 farms engaged in commodities production, maximizing efficiency is the primary operational focus, creating a strong motivation to adopt precision agriculture (PA) techniques.

Type 3 farms are mostly engaged in the production of fresh goods for export markets in developed countries, where strict safety and quality standards prevail. The retail segment, primarily supermarkets and hypermarkets, in receiving countries is responsible for the coordination and supervision of these standards. Wine grape producers in Chile, citrus fruit producers in Argentina and flowers producers in Colombia and Ecuador are examples of type 3 farms. In these operations, farmers are typically linked with downstream, post-harvest distribution and marketing firms. Identity preserved (IP) systems and traceability systems are beginning to diffuse among these kinds of farms. When part of the production is for domestic or regional markets where standards, although increasingly important, are lower than those prevailing in industrialized countries, local distribution firms are responsible for chain governance. Early warning and climate information systems are gaining importance in type 3 farms, to limit crop losses and prevent damage to the cosmetic appearance of fruits and vegetables caused by pests, diseases or extreme weather events.

Types 4 and 5 farms include dairy and livestock production. ICTs are increasingly employed in these operations to either comply with regulations in export markets (traceability), or to achieve greater operational efficiencies through new techniques like precision dairy systems. In dairy, the standards imposed by the processing industries or the marketing and distribution chains are the main drivers for the adoption of new technologies, while in cattle production the primary drivers are new regulations requiring animal traceability.[79]

[79] There are important differences among LA countries in traceability standards and enforcement practices.

Table IV.2 delineates the main features in the information management process and categorizes them by farms type. It should be kept in mind that there are important differences between farms belonging to the same type. As shown in the table, all farmers rely on both external and internal sources of information, but great differences exist between types in the kinds of practical knowledge and information handled by farmers and their absorption capacities and learning styles.

Table IV.2

Farm type and ICT knowledge in Latin America

Farm type	ICT Knowledge		
	Information and Knowledge sources	**Formalization**	**Technological knowledge of farmers**
1. Large/medium-sized farms for extensive crops (mainly grain and oilseed production), primarily owner-operated, but including some rented-land operations	Internal: consultants, technical advisers External: interactions within the value chain - suppliers, customers and ICT learning networks	Tacit: based on experience and routines Codified: consultants and agronomists; input and machinery suppliers	Know how - Know what -Know Who
2. Agricultural management enterprises (AME) that manage their own farms and also provide financial, technological, logistical, marketing and risk management services to other farms.	Internal: consultants, technical advisers External: interactions within the value chain - suppliers, customers and ICT learning networks	Tacit: mainly the ability to coordinate the business network Codified: consultants and agronomists; input and machinery suppliers	Know how - Know what- Know Who
3. Medium/small-size, export-oriented farms managed by owners or tenants (mostly fruits and vegetables)	Internal and external by interactions within the value chain (mainly suppliers)	Tacit: based on experience and routines Codified: consultants and agronomists	Know how - Know what - Know who
4. Medium/large-sized dairy farms	Internal: experience-based learning External: interactions within the value chain, mainly customers	Tacit: experience-based and interactions with customers Codified: standards and regulations	Know how - Know what
5. Cattle production	Internal: experience-based learning External: mainly with suppliers	Tacit: experience-based and interactions with customers Codified: standards and regulations	Know how

Source: Prepared by author

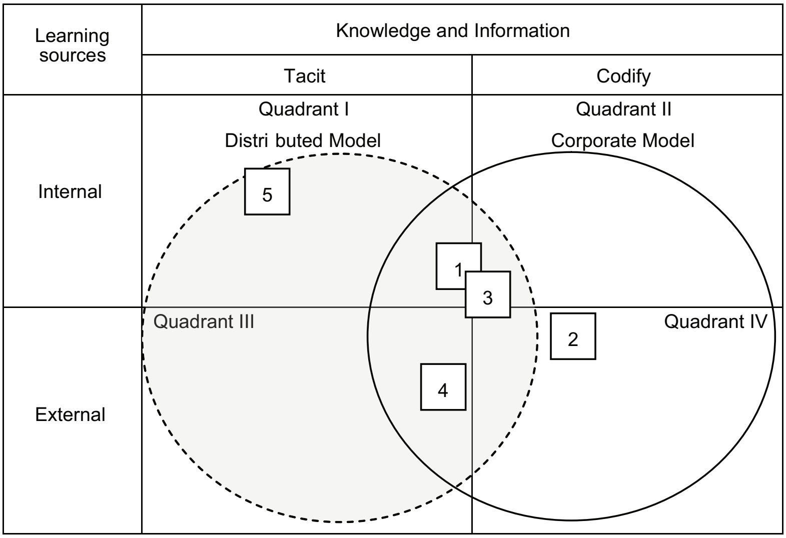
To understand the different ways the learning process occurs in the agricultural sector, and the role of ICTs in this process, it is necessary to consider all the agents and firms involved and their position in the value chain. Farmers, even though they are the final users of the new technologies, are not always, nor necessarily, the actors to whom these technologies are addressed. Within agro-industrial networks, suppliers of specialized services play the role of translators or facilitators in the interface between new technologies and farmers. These networks are comprised of a variety of different agents: young farmers with technical capabilities, technical advisers like agronomists and veterinarians, different types of suppliers (of inputs, equipment, specialized software and agricultural and technological services), universities and R&D institutions, public and private rural extension services, private farmers and value chain associations (such as the CREA groups in Argentina and Uruguay) and cooperatives. Although the role of the farmer is more relevant in some instances, based on his experience and his knowledge of the specific traits of his farm, the central participants in the learning processes are, in the majority of cases, the suppliers of specialized services.

3. A typology of commercial farmers' learning processes

Taking into account the contributions of Antonelli (2011), we assume that the learning modalities of commercial farmers are affected first by the relative importance of tacit and codified knowledge to the participants in the innovation network and by the degree of formalization of the learning processes resulting from the systematization of information. Secondly, they are affected by the relative importance of the internal and external sources of learning, i.e., by the place commercial farmers have in the value chain and in innovation networks and the access they have to external knowledge. We postulate that the impacts of ICTs on the farmer's technological learning process will be affected by the modalities of the learning process.

Figure IV.2 shows the relationship between tacit and codified knowledge and internal and external learning sources. We are assuming some minimal level of overlap between both sets of variables and a hierarchy between types of knowledge and learning sources. It is assumed that external learning sources cannot be accessed without the prior development of internal sources, whether formal or informal, tacit or codified, and that tacit knowledge is needed in order to interpret codified knowledge (Antonelli 2011, Cowan, David and Foray, 2000).

Figure IV.2
Learning processes of commercial farms according to sources of learning and knowledge types



Source: Prepared by author on the basis of Antonelli (2011)

Antonelli distinguishes two theoretical learning process models: distributed and corporative. In the first model the distribution of tacit knowledge among network participants prevails. The distributed model emphasizes the tacit knowledge available in the network, the learning processes based in the supplier-user interactions and the capability of technology suppliers to improve their products and services as a result of their interactions with users. Users may improve their economic performance and efficiency, as in the case of precision agriculture, or follow a strategy of innovation for high quality products (see case studies in the next section).

On the other hand, the corporative model emphasizes codified knowledge because of the importance of research activities and the coordination of various sources of codified knowledge (different techniques and technologies). In this model, designed especially for the analysis of learning processes in large industrial corporations, external knowledge sources are also codified in nature (patents and licenses). New knowledge can be developed through the recombination of existing knowledge. In agro-industrial value chains, the corporative model is found in MNEs in the agrochemical and biotechnology sectors.

As long as farmers access new technologies through technology providers and advisers, they will be placed near or below the horizontal axis of figure IV.2. If the adoption process requires a high level of codified knowledge (rules, procedures and so on), they will be placed near or to the right of the vertical axis. The following analysis applies to figure IV.2:

- Quadrant I: includes farmers with high internal learning processes based on experience and *know how*. Antonelli refers to the intersection between internal sources and tacit knowledge as experience-based learning.
- Quadrant II: includes two types of codified knowledge: *know why* —scientific knowledge based on research activities— and *know what* —knowledge incorporated in instructions and guides. According to Antonelli this quadrant is characterized by learning processes based on R&D activities whose main outputs are new codified knowledge in the form of patents, handbooks, internal procedures and so on.
- The lower half of the figure (Quadrants III and IV) shows the relevance of external knowledge sources: *know who* —the ability to find the appropriate partners and resources within a network.

The different types of farmers described in table IV.2 have been placed in figure IV.2 according to the kind of knowledge they mostly use. Farmers who succeed in combining internal and external learning sources and codified and tacit knowledge will be in a better position to adopt ICTs and the application of the technologies will have positive impacts on the management of information and the administration of the farm. This category includes farmers of types 1 and 3 and, to a lesser extent, types 2 and 4.

Type 2 and 4 farmers, with learning processes based on interactions, have been placed in different positions according to the relative importance of codified knowledge within the type. It is expected that type 4 farmers will obtain higher benefits from ICT applications because of the high level of codification of the information important to the food industry and in product quality assurance systems. Conversely, because of their short-term strategies, type 2 farmers are not as interested in developing internal sources of knowledge. ICTs have a limited impact on the management of production on type 2 farms, but play an important role in financial management activities.

Farmers with relatively high learning restrictions rely heavily on internal knowledge sources based on experience and show difficulties in coordinating external and internal knowledge, not only because of their weak position in the network, but also because of their limited internal capacities. This might be the case, for instance, with cattle producers for domestic markets in Argentina (see case studies). The potential of ICTs for information management seems to be limited in this sector owing to the high level of informality that prevails among these producers, which constricts the codification of information. New regulations requiring traceability systems for domestic markets will force changes, but for the moment ICTs play an important role only in the case of producers oriented to export markets. For these producers, traceability systems may additionally contribute to improving the efficiency of farm operations.

Table IV.3 shows how ICTs are diffused, according to farm type.

Table IV.3
Farm types and ICT diffusion

Farm type	ICT Diffusion		
	Highly-diffused ICTs and software applications	**Reasons for use**	**Adoption drivers**
1. Large/medium-sized farms for extensive crops (mainly grain and oilseed production), primarily owner-operated, but including some rented-land operations	Generic ICTs and software applications; PA tools	Reduce costs, increase yields	Input and machinery suppliers, machinery contractors, technological services suppliers, technology translators
2. Agricultural management enterprises (AME) that manage their own farms and also provide financial, technological, logistical, marketing and risk management services to other farms	Generic ICTs and software applications; PA tools	Reduce costs, increase yields	Input and machinery suppliers, machinery contractors, technological services suppliers, technology translators
3. Medium/small-size, export-oriented farms managed by owners or tenants (mostly fruits and vegetables)	Generic ICTs and software applications; some PA tools; traceability technology	Reduce costs, increase yields, differentiation strategies, market access	Input suppliers, technological services suppliers, upstream actors in value chain
4. Medium/large-sized dairy farms	Generic ICTs and software applications; some PA tools; traceability technology	Differentiation strategies, market access	Input suppliers, technological services suppliers, upstream actors in value chain
5. Cattle production	Generic ICTs and software applications; traceability technology	Differentiation strategies, market access	Generic translators

Source: Prepared by author

[a] *Generic ICT devices and software applications: mobile technologies, internet, e-banking, farm management and accounting software, agricultural information portals.*

[b] *Generic translators: agricultural consultants, farmer associations, universities, public agencies.*

D. Case studies

To analyze the impacts of ICTs on producers' information management, we looked at more than 30 articles and documents focused on the study of the application of ICTs in the agricultural sector. Additionally, we conducted a series of interviews with regional experts (see References).

The articles and documents reviewed were focused mainly on the description and analysis of the impacts associated with the diffusion of ICTs by public programs aimed at supporting rural communities. In many cases, these programs are joint efforts between international organizations such as the IADB, GTZ, FAO IICA and others, and rural extension services (INTA in Argentina, FIA in Chile, INIA in Uruguay, MINAG-DGIA in Peru), universities, rural professional associations and local businesses (some examples are: FIA, 2008, IICA, 2010, Carosio, 2008).

Few publications are focused on the innovation and learning processes associated with the diffusion of ICTs in the agricultural sector, considering subjects such as the impact of ICTs on increasing the efficiency of farming processes (reducing costs, increasing yields, improving market access and so on), or on farmers' information management (some examples are Bosch, 2007 and Schneider, 2010).

The five cases selected are presented following the same analytical structure. We first present a general description of the topic and, when available in the current literature, a general overview of the situation in Latin American agriculture. We then present some successful examples in Latin American agriculture and, in some cases, from other regions. Lastly, we discuss the potentials and constraints associated with IM and the diffusion of the particular technology discussed.

a. Agricultural information systems and early warning systems[80]

Generic ICTs, especially communication technologies such as cellular telephony, internet telephony systems (VoIP) and other mobile devices like PDAs, are those most widely diffused in the agricultural sector. They are less costly relative to other technologies and enable farmers to more easily access, gather and share information and reduce transaction costs

[80] This case is based on IICA, 2007 (Instituto Interamericano de Cooperación para la Agricultura), RIAN and SINAMIVO websites, and interviews with key informants.

In this environment, specialized agricultural web portals have multiplied and are delivering increasingly specific and dedicated services. The need for access to internet-based agricultural information networks —whether local, national or regional, public or private— and for tools for gathering and storing information is driving the adoption of ICTs. The networks, made up of multidisciplinary teams, provide updated agronomic and weather information and early warnings on the probability of pest and disease outbreaks.

Since these kinds of information services are relatively new and studies analyzing their impacts are scarce, it is difficult to measure and assess their impacts on farmers' IM. However, the experts consulted agreed that these types of generic ICTs facilitate and improve farmers' decision-making abilities and the overall business management of agricultural enterprises, increasing their efficiency and competitiveness.

Outstanding examples

The selected examples of weather information networks for agriculture, with or without early warning systems, are diverse, ranging from generic to more specific and dedicated information services, with the latter having more impact on farm information management.

- In Argentina there are two nationwide public systems: (i) the Argentinean National Pest Surveillance and Monitoring system (SINAMIVO) that provide(s) general updates on the health status of the main crops in the country, according to the international standards set by the International Plant Protection Convention of FAO.[81] This system has a database of major pests in Argentina and is capable of making searches for specific pests that are affecting crops in any region of the country. The SINAMIVO reports can be accessed through its website, by telephone and by email; and (ii) The National Agricultural Information Network (RIAN) operated by INTA. Their website-based[82] services include mapped green-rate images collected by a satellite-based sensor system that provide information on vegetation characteristics, including biomass, leaf area, and productivity and meteorological information, including rainfall maps, generated from a land-based electronic sensor system.

81 http://www.sinavimo.gov.ar.
82 http://rian.inta.gov.ar.

RIAN is connected to a regional network with the most comprehensive database of agricultural information on the Pampas region (RIAP). INTA Experimental Units participating in RIAP develop databases that support various research efforts in their respective regions. These data are fed into a geographic information system (GIS) that provides spatial information for analysis and decision-making.

Both programs offer an e-mail newsletter service with information specific to the user's location, online databases, and online services based on interactive maps. National cell phone alert systems will soon be available, according to the experts we interviewed. Based on assessments of other cell phone early warnings systems developed by INTA experimental stations like Anguil (Bellini et al, 2009) and Concordia Station Frutic (Stablum et al, 2009), we believe that agro-weather information networks linked to local agricultural markets would be the best providers of these services.

- In Chile, the public-private Agriculture Climate Information system[83] is a partnership of the Fruit Development Foundation (FDF), the Institute of Agricultural Research (INIA) and the national meteorological office (DMC). This system collects data from automatic weather stations that feed information on rainfall, solar radiation and atmospheric pressure into a central server. On the basis of this information, the system produces weather reports that are distributed weekly via e-mail and issues pest and weather alerts, including frost and extreme temperature warnings and precipitation forecasts. In addition to these reports, the network provides a fee-for-service cell phone warning system.

- In Brazil, the decision support system for the control of Asian rust in soybeans provides an interesting example of a complex information network with an alert system based on modeling. The system uses simulation models to anticipate the emergence of Asian rust fungus in soybeans in the state of Paraná. Early warnings allow farmers to take specific courses of action according to observed conditions, particularly in relation to the use of fungicides, which can help reduce input costs. Results show that the system has helped to reduce production losses and increase the effectiveness of fungicide applications.

83 www.agroclima.cl.

It should be noted that the system does not specify possible courses of action to be taken by farmers under different scenarios because of the variability in site-specific conditions. Farmers often require the assistance of technical advisors to combine the information provided by the system with farm-specific conditions to determine the most appropriate response.

- In India, the e-Choupal programme serves over four million farmers in more than 40,000 villages and is an outstanding example of an effective agricultural information network. The award-winning programme was created by ITC Ltd.,[84] one of India's largest exporters of agricultural commodities. It provides village internet kiosks managed by local farmers (called *sanchalaks*) that give the agricultural community access to market and weather information (in their local language), disseminate knowledge on scientific farm practices and risk management, facilitate inputs purchases and enable farmers to sell their produce directly from their doorsteps. Farmers benefit through, lower costs, enhanced productivity and higher farm gate prices.

Potential and constraints

The above examples show that the potential of various agricultural information systems to improve farmers IM is higher when the systems manage and deliver area or site-specific information. Additionally, the information has to be built and distributed across networks, which requires interaction among different actors and active participation at all levels, from network coordinators to final users. In order to maximize their potential these technologies require user training and the active role of the professionals and technicians involved.

b. Precision agriculture in extensive crops[85]

In the early nineties, civilian access to the Global Positioning System (GPS) opened up possibilities for the development of intelligent devices for the site-specific management of agricultural operations, offering the potential for greater efficiency in the use of inputs. Known as precision agriculture, these practices started to spread in the mid-1990s.

84 www.itcportal.com.

85 This case is based on Bragachini et al, 2005; Bragachini, 2006; Corró Molas, 2007 and several key interviews.

PA, or site-specific crop management, can be defined as the management of the spatial and temporal variability in agricultural production at a sub-field level to reduce costs, improve economic returns and reduce environmental impacts. PA is an information intensive technology. The main activities associated with this technology are data collection, data processing and interpretation and variable rate application of inputs (Chartuni et al, 2007). It uses a wide range of information and communication technologies, many of which are incorporated in agricultural machinery, including GPS, electronic devices like temperature, moisture, and green index sensors, yield monitors, and sample meters, which in combination provide precise crop information and enable the location-specific administration of inputs (Bragachini, 2006; Albornoz, 2006).

PA is used in North America, Northern Europe, Australia and some Latin American countries, mainly in corn, soybean and cotton production. Yield monitors connected to GPS receivers were the first tool used for site-specific farm management, enabling variable rate applications of fertilizers and chemicals (Fountas et al, 2010).

Outstanding examples

In Argentina, PA has been used in crop production in the Pampas since 1996. This experience shows some of the advantages and potentials of this technology. According to Bragachini et al (2005), the main applications of PA in Argentina are associated with (i) the control of various activities (yield monitors, GPS guidance); (ii) data collection (yield monitors to monitor the protein, oil, fat and moisture content of grain, real-time sensors, aerial photographs and satellite maps); and (iii) analysis and management (specific software to determine seed density and fertilizer application rates).

Argentina ranks second after the US in the number of performance monitors and fifth in number of screens per hectare planted (Bragachini, 2006). INTA Manfredi estimates that about 20% of the total land in extensive agriculture is managed using practices associated with precision agriculture.

The most widely adopted technology is GPS guidance because it reduces labor requirements for applying chemicals while minimizing the risks of exposure to toxins. The use of performance monitors (PM) is the second most widely adopted practice while variable fertilization (VF), applied mainly with spray systems, is at an early stage of diffusion (Corró Molas, 2007).

The high cost of the intelligent machines for harvesting and spraying and the fact their use is limited to specific points in the production cycle has led to the emergence in Argentina of agricultural machinery contractors and the outsourcing of these operations. According to Casal (2011) most of the harvesting and about 70% of the spray tasks are now performed by contractors. Because of this, service contractors, not farmers, have been the main adopters of PA-associated technologies in Argentina, although in some cases the contractors also own and farm their own land.

The rate and scope of PA adoption and diffusion in industrialized countries and the factors limiting its application are of interest when considering the potential of PA in Latin American agriculture. Several studies (Gelb and Offer, 2010; Foutas et al, 2010; Sonka et al, 1999) point out that PA has not been widely adopted by farmers in the United States and Europe and, when adopted, farmers are a decade younger than the average farmer and cultivate larger farms than the average farm holding. Among the reasons for the slow rate of diffusion are the high cost of the specialized equipment required for PA and the need for extensive operator training. The potential returns from PA, as reported in surveys of farmers, do not justify the costs involved (Fountas et al, 2010)[86]. Ongoing costs can be relatively high because yield variations within a field differ from year-to-year due to the complex interactions between factors such as soil type, temperature and the incidence of disease. For these reasons, the information needed to calculate the application of inputs must be continuously revised and adjusted with consequent impacts on costs. In addition, the available decision support system (DSS) software has not adequately incorporated the agronomic and economic interpretations needed to transform the data gathered into useful decision-making. All these factors elevate the importance of PA specialists and technology services suppliers —crop advisors, fertilizer dealers, extension experts and the like— working in close collaboration in networks, including research institutes and universities, as facilitators of specific on-farm tasks and providers of basic agronomic information, (Fountas et al, 2010 and Offer, 2010).

[86] Compared to genetically modified crops, the adoption of PA practices has been relatively slow because PA is a time demanding approach (for analysing data, learning new farming procedures, attending meetings, courses and workshops), while GMO crops are time-saving. Additionally, the techniques and management skills required to use the GMO crops were already established when the use of GMO seeds started, while in PA the agronomic and economic evaluation and data analysis was not very developed when the first tools were introduced.

Potential and constraints

The evidence gathered in the case of Argentina shows that when these technologies are successfully applied there are significant cost reductions. PA tools not only allow a more efficient use of inputs and resources at the individual farm level, but also facilitate the wider dissemination of information on best practices within the network of users. However, the diffusion of PA is constrained for a number of reasons:

(i) Similar to what happens in industrialized countries, the main adopters of PA in the Pampas region are large farms (types 1 and 2 in our farm typology) which represent only 5% of the total farms in the country. The network for the application of PA includes farmers, technical advisors (on-farm or contracted), technological input suppliers, PA contractors, specialized services providers, INTA and other public and private R&D institutions and farmer associations such as CREA (*Asociación Argentina de Consorcios regionales de experimentación agrícola*). The extension office specializing in these technologies (INTA Manfredi) is promoting the dissemination of PA to medium-sized farms in the region (type 3 in our typology). Working in close collaboration with the suppliers of technological inputs and networking with research and extension institutions, these farmers provide the specific field and agronomic information to the technology providers, facilitating and improving the adaptation of PA equipment to their farms.

(ii) The increasing complexity of machinery, computers and specialized software requires the training of operators, with consequent increases in costs. Specialized technology service providers are central to the process of determining the appropriate level of input applications due to the complexity of the required data analysis (Rebella, 2011; Mendez, 2011).

(iii) The beneficial implementation of PA depends on an adequate characterization of farm sub-plots and the price of inputs. Mendez et al (2011) indicate that the potential improvement in profitability due to the variable application of inputs depends on the identification of areas in the field in which additional application of inputs significantly increases revenues in proportion to the additional costs, or the identification of areas in which the reduction in input costs is greater than the potential reduction in revenue due to lower yields.

c. ICTs and precision agriculture in intensive farming[87]

Precision agriculture is also beginning to gain a foothold in some high value intensive crops that can benefit from identifying, quantifying and mapping intrafarm plot variability for the more precise application of farm inputs.

While there are relatively few examples of the use of PA in intensive crops in the region, viticulture is one area where PA techniques are being applied. The application of PA in wine grape production is relatively recent, beginning first in the late nineties in the US, Europe and Australia.

Until recently, there was no tool that could adequately map the spatial variability within a vineyard, particularly in relation to soil and plant characteristics. Precision viticulture techniques can now be applied using uniform aerial images —multispectral imaging— captured by specialized cameras and GIS techniques, to gather and analyze the necessary information. These images enable the employment of PA techniques to create the conditions for the vigorous growth rates that produce higher quality grapes (Chartuni et al, 2007).

Outstanding examples

In Chile, the use of PA in vineyard management is spreading. Adopted in vineyards producing grapes for higher quality wines, PA is used primarily for site-specific irrigation planning and seeks to optimize production and grape quality by maintaining a balance between fruit load and leaf area. Precision techniques enable a more efficient use of inputs and harvest scheduling based on the varying grape maturity rates in the vineyard.

One study (FIA, 2008b) showed that the implementation of PA for irrigation management in a 150 hectare vineyard resulted in cost reductions of 6% and a 4% increase in production. The results far outweighed the costs of equipment installation, associated data collection and interpretation and related operational changes.

[87] This case is based on FIA, 2008b; Chartuni et al, 2007, and interviews with key informants.

Potential and constraints

The successful implementation of this technology requires specialized training for growers and technical advisors and the necessary managerial and financial resources. These requirements will probably limit PA in viticulture to larger vineyard operations (FIA, 2008b). Currently, PA has spread mainly in the stratum of vineyards producing higher quality grapes, which account for around 40% of the land in production, on a total of 45,000 hectares[88].

The main barriers to the adoption of specialized ICT tools for small and medium-sized vineyards are similar to those for other small farmers in Latin America: high costs, lack of broadband or internet connections, financing, training and cultural factors. Figures presented by CISCO (2008) show that most large vineyards (more than ten hectares) —approximately 2,400 vineyards— are owner managed and, in almost all cases, have Internet access. Internet adoption among the approximately 6,000 medium-sized vineyards (between one and ten hectares) varies among regions depending on broadband penetration. All farmers in these categories have basic ICT knowledge. At the other end of the spectrum, are small vineyards of less than one hectare —some 5,600 vineyards— whose owners/operators have some basic level of PC adoption, but which are often managed by older farmers who have little or no ICT knowledge or skills.

The adoption and diffusion of PA in intensive crop production has followed the same path as that seen in extensive agriculture and for the same reasons: high capital costs and the need for high levels of learning and training. Adoption has been driven in large part by the demands of other actors in the agro-food chain and by international markets. Capital costs are a major constraint to future growth.

d. Traceability systems

Traceability systems were established in the meat industry to ensure safety and quality standards primarily as a result of concerns related to livestock

88 The Chilean wine industry: Chile has more than 13,000 vineyards and 450 wineries. Seventy-four per cent of the wine produced is exported. For premium wines, wineries own their own vineyards and/or have long-term contracts with selected vineyards. Labor and raw materials account for 54% of total costs. Notwithstanding the recent vineyard consolidation process, vineyards are still very fragmented in Chile, with small vineyards (smaller than 5 hectares) accounting for 72% of the total cultivated area. Vineyard consolidation has occurred mainly as a result of the principal wineries buying smaller vineyards as part of their expansion plans (Cisco 2008, from different sources).

disease[89]. In response to these concerns a growing number of countries have promulgated strict new labeling regulations and have mandated traceability systems. According to ISO 8402, cattle traceability allows the identification of an animal along the supply chain from birth to end market. Currently, most meat-exporting countries have national legislation mandating some form of traceability system to ensure access to foreign markets and, in some cases, for domestic markets as well. The goal of these regulations is to create transparency in the meat production chain, provide more product information to consumers, to meet the requirements of foreign markets and to support programs for the eradication of foot and mouth and other livestock diseases.

Traceability systems are also being used for a variety of other purposes related to value-added marketing, like geographic origin and organic products. In this regard, traceability systems facilitate access to markets and provide new opportunities for product differentiation. Traceability systems are information intensive; hence, ICTs play a key role. The level of use of ICTs in traceability systems varies depending on the type of system employed. Electronic tracing, in contrast to analogue systems, allows better record-keeping and a greater degree of integration with other farm management systems. Systems that are limited to public registration purposes are generally less data rich and less useful as a tool for production management. Computerized traceability systems have led to improvements in livestock management, as in Uruguay.

Over the last ten years, South American meat exporting countries have promulgated a variety of regulatory systems for livestock registration. Table IV.4 shows the main differences between these systems. Not all of them are digitized, or at least digitization is not mandatory. Uruguay is the only country that requires digitized traceability. In Brazil, although not mandatory, the most commonly used identification devices are electronic. In Argentina, due to the high levels of informality in the beef industry, recordkeeping systems are scarce and the regulations are repeatedly violated. Digitized systems in Argentina are generally limited to the export segment of the chain.

[89] The main livestock diseases are: Bovine Spongiform Encephalopathy or mad cow disease, escherichia coli, swine fever and foot and mouth disease.

Table IV.4

Traceability systems used by Latin American beef producers, by country

Country	Year	Regulatory extent	Identifier type	Regulator
Argentina	2003 and 2007	Since 2003 for export livestock, since 2007 for all livestock	Visual Caravan identification numbers and colors. Paper registration, including gender, breed and animal health records.	SIGBE (Sistema de Identificación de Ganado Bovino para Exportación) SENASA
Brazil	2002, 2004 and 2006	All cattle destined for export and, since 2006, all calves born in FMD-free areas whether or not intended for export.	Visual Caravan identification numbers. Other identification is optional. Producer can choose between tattooing, branding, electronic devices, or visual headset button. Additionally, should follow a basic record-keeping protocol for production inputs.	"Serviço de Rastreabilidade da Cadeia Produtiva de Bovinos e Bubalinos" Ministerio de Agricultura, Pecuaria y Abastecimiento (MAPA).
Uruguay	2006	First Latin American law mandating nation-wide traceability	Stakeholder access to the recorded information through the "National Livestock Information System" (SING), custom-designed software, georeferenced GIS system. SEIIC computer system controls all cattle slaughter and final product traceability.	SIRA (Sistema de Identificación y Registro Animal) and INAC (Instituto Nacional de E7Carnes) which controls the industrial phase. Ministerio de Ganadería, Agricultura y Pesca (MGAP)

Source: Prepared by author on the basis of AHCIET (2010)

Outstanding examples

In Argentina[90], the Trazar Foundation has spearheaded a cooperative effort by livestock producers to develop and implement a computerized traceability system. The tracking system —TRAZ.AR— is used by medium-sized beef producers in Entre Rios province who are partners in a consortium for exporting quality meat to Italy. It includes components for recording information, managing the information in a centralized database and distributing it to participants in different stages in the chain —breeding, wintering, slaughtering, logistics, distribution and marketing— and to end consumers. Entering an identification number provides access to complete information about the production process and the individual animal's history. The system ensures traceability and enables producers to efficiently access key information for herd management such as vaccination records, growth rates and weight. Information can also be retrieved by other users

90 This case is based on AHCIET, 2010; Albornoz 2006, Araoz 2004, and Irurueta 2011, Fundación Trazar website and personal interviews.

—firms and trade associations, public health agencies, certifying bodies and consumers— that have different levels of access depending on their needs. Audits are conducted to guarantee compliance with quality and safety standards. Participating producers have improved the management of their herds and guaranteed their access to international markets, resulting in better financial returns from their operations.

Traceability systems developed by the Trazar Foundation are beginning to spread to different crops and regions. For example, the cattle traceability program is being used in Nicaragua and by FRUTIC, an association of citrus growers in the province of Corrientes in Argentina. There are several institutions and associations involved in this project, including international funding agencies (IDB); local associations such as the Asociación Cultural para el Desarrollo Integral;[91] national public institutions (INTA, CERIDE-CONICET, MINCyT); and producer associations like PROGAN (in the Province of Santa Fe in Argentina), a consortium created for the pilot system and a major user of the system. Its quality protocol was developed jointly with the University of Parma, in Italy, since Italy is the major export destination.

Potential and constraints

Despite the potential benefits of traceability, the adoption of these technologies is a long and costly process for producers. National regulatory systems are being implemented in LA with differing requirements, rates of adoption and levels of enforcement based on the stage of development of the meat sector and product end markets (AHCIET, 2010).

- Brazil and Argentina have chosen to initially implement traceability for meat produced for export. Other producers can participate voluntarily.
- Uruguay, an early adopter of traceability, has taken advantage of the transition towards individual animal traceability systems to move from visual to electronic identification systems. This has allowed the development of databases with complete information on the herd, which has led to improvements in the production process and encouraged learning related to process innovations.
- Countries that are just beginning to implement their traceability systems have initially adopted more rudimentary approaches and electronic systems are still optional. Compliance with the standards

91 www.acdi.org.ar.

for traceability systems are generally beyond the capabilities of small farms and one consequence of the implementation of traceability systems is an increase in average farm size.

The coordination or governance in these quality and safety control networks is the responsibility of companies located in the final stages of the value chains. With the increasing dominance of private standards, large multinational retail distribution firms are becoming the strategic nodes of economic power and chain governance. There are, however, some market niches in which groups of producers are collectively monitoring their food safety standards and benefitting from reduced transaction costs (Henson and Reardon, 2005; Narrod et al, 2009). Public and private (supermarkets) food safety and quality standards are important driving forces of agrifood systems in developing countries , in response to regulatory developments, consumer concerns and competitive positioning. Certification, labeling and branding systems that link high quality and safety standards to the product are intensive in ICT, which help to coordinate procurement chains. Some case studies on private standards adoption in Latin American agriculture provide indirect evidences of the importance of ICT for these processes. Farina et al. (2005) discusses the cases of milk production in Brazil and Argentina; the case of vegetable supermarket suppliers in Costa Rica is discussed in Berdegue et al. (2005); and Mainville et al. (2005); explores the nature of firm-level decisions regarding the use of public and/or private food safety and quality standards of the market for fresh produce in São Paulo, Brazil.

e. Software for agriculture: The supplier-client learning process [92]

IT needs within the agricultural sector differ significantly and are influenced by a wide variety of factors including the type of production, the complexity of the value chain and the market and regulatory environment. Management systems for cattle production, for example, differ from systems for dairy herd management or other livestock operations. In turn, the systems that are optimized for extensive agricultural crops are not suitable for intensive crops and vice versa. The development of appropriate, effective applications requires a close working relationship between clients and IT suppliers. Software suppliers for the agricultural sector must look to a variety of other sources for information and feedback, including chambers of commerce and other business associations, technology centers and universities.

[92] This case is based on AHCIET (2010), Albornoz (2006); Albornoz and Robert (2008) and Yoguel et al (2010).

In conjunction with the diffusion of ICTs in agriculture in LA, specialized IT service providers and software developers for farm management have emerged. In addition to firms in the private sector, public institutions and non-governmental organizations play an important role in IT development for agriculture.

Outstanding examples

In Argentina, the growth of the software development and IT services sector over the past 20 years has given rise to a relatively dynamic sub-segment that is creating custom software applications for agriculture. Rapid growth in agriculture in LA has fuelled growth in the IT sector that specializes in meeting the informational needs of agricultural producers.

As well as developing new products, these new IT providers are important suppliers of post-sales training and support services. The most popular products and services from these companies are teaching and farm management tools, among them: (i) business management systems; (ii) resource planning and optimization systems; (iii) custom applications; and (iv) consulting services and technical training software.

Client-supplier interaction plays a central role, both in the emergence of specialized firms and the development of their core products. Most firms have staff members with agricultural backgrounds (farmers, agronomists) and in other cases the founders are close relatives of farmers or contractors. Often young farmers pursuing information technology studies develop computer systems for managing the family business (Albornoz, 2006). Even if young farmers do not have previous IT training, they are, in most cases, actively involved in the adoption of new technologies.

EMBRAPA, the Brazilian Agricultural Research Corporation, holds the technical expertise to support and foster the use and development of free software for agricultural sector. It has developed a set of open license software for a variety of users and launched the Free Software Network for Agriculture (AgroLivre) with the purpose of satisfying the agricultural sector demands, in areas such as decision support, scientific research supporting tools and digital inclusion. Embrapa Information Technology is responsible for the coordination of the free software repository for the agricultural sector. This activity is crucial to share information, databases and software among producers and the different agriculture extension offices. Some software can be modify and suit to different regions problematic.[93]

Potential and constraints

The development of partnerships and networks for the generation and dissemination of such technologies, in which farmers and technical and specialized service providers play complementary roles, is critically important. The agricultural sector has to provide the information software developers need to create specific IT products adapted to their operations.

The supply of effective IT solutions can be constrained by the difficulty farmers may have in communicating their specific needs and by the uneven development of the software industry and IT services in various LA countries, which can be a disadvantage in countries that need to import software solutions not tailored to their regional specificities.

E. Concluding remarks

In the modern technological paradigm, the agricultural sector has increasingly become an information intensive economic activity. Farmers need different kinds of information to administer their farms and manage production, to know about inputs and markets —which have become more and more sophisticated— and to access and utilize new technologies and agronomic techniques.

Intangible assets are becoming increasingly important. Historically, physical assets —land, livestock and equipment— and their control were at the centre of agricultural production. In modern agriculture, while those factors continue to be of critical importance, new skills, especially information management capabilities, are necessary for building linkages and relationships across the value chain, to evaluate alternative production systems, to monitor economic and market developments and to understand the economic and strategic benefits of the new technologies.

We have given several examples to illustrate the importance of ICTs in managing the information available to farmers and as enabling

93 For more detail see EMBRAPA web-page.

technologies for the implementation of new agronomic techniques and more sophisticated management tools. ICTs foster the adoption of associated technologies and can also reduce operating and transaction costs in the production stage and transaction costs in distribution and marketing activities.

In South American agriculture, ICTs have diffused mainly among large farms engaged in grain and oilseed production for export, small and medium-sized intensive-crop farms specializing in products for export markets and farms and livestock operations that produce goods subject to national and international food quality and safety regulations.

The diffusion of ICTs and related tools is taking place in information and learning networks which act mainly as support systems in the farmer's productive activities. However, the learning processes associated with these technologies are focused on other actors in the agro-ICT networks, particularly agricultural advisors and technology and service suppliers who interact directly with input and machinery suppliers.

There have been significant changes in the business management of the farm as a result of the diffusion of, and better access to, data and information. We have stressed the actual and potential importance of ICTs as enabling technologies and drivers of technological change and as a means to improve the farmer's ability to manage technological knowledge.

Access to ICTs, in and of itself, cannot break down the barriers imposed by the economic asymmetries between farmers or their differing information and knowledge absorption capacities. It is even possible that the diffusion of ICTs creates new barriers and asymmetries that exacerbate rather than ameliorate the scope and negative impacts of the digital divide because of the knowledge and economic hierarchies in the value chains and the barriers that constrain the creation of the new capacities and cultural models needed to reap the economic benefits available from the ever-increasing amount of data and information. In other words, the knowledge and structural heterogeneities that already prevail in the agricultural sector can be aggravated because of unequal access to these new technologies.

Even if ICT adoption enhances the comparative advantages of the whole value chain and of producers and firms engaged in the innovation networks, are the resulting benefits proportionally distributed between all participants or do they accrue disproportionally to certain players? For instance, networks comprised of large agricultural enterprises and small farmers, where the first play a management role and provide technological, financial, logistic, and commercial and risk management services to the small producers, are beginning to emerge in some developing countries. These networks are certainly important mechanisms for the diffusion of ICTs that enable the dissemination of new production techniques and access to information and other strategic assets. However, the concentration of economic power in large farms often produces disparities in the distribution of the benefits that accrue from modernization in the producer segment of agricultural value chains. These kinds of disparities are magnified because of the power asymmetries between farmers and firms operating in the input and distribution and marketing stages of the chains.

It is not enough to have access to data and information. Although access to information and the farmer's capacity to process that information are important elements in decision-making processes, the potential impacts on farm management are conditioned by access to other strategic assets, including equipment and inputs, financing, and market channels. For instance, to apply the information captured by remote sensors about plot-specific differences in yields, farmers need to have access to intelligent machines equipped with the sophisticated electronics that enable application of variable rates of inputs. In the same sense, it is not enough to have real-time information about market conditions and prices if the farmer does not have access to the appropriate distribution and marketing channels, or if they are tied into asymmetric contractual relationships in the value chain that determine what or when to produce and to whom and at what prices to sell. Additionally, it is not just a question of better access to information, but also, as stressed by Chapman and Slaymaker (2002), whose reality the information reflects and, most importantly, who is able to make use of the information and for what purpose.

The ICT revolution is transforming Latin American agriculture. The exponential improvements in the tools available to farmers to create and manage knowledge and information have provided new means to reduce costs, improve productivity and develop competitive advantages. However, notwithstanding their potential democratizing effects, the uneven diffusion of ICTs in the region continues to be a significant barrier to a more equal distribution of the benefits that accrue from these new technologies. Information management associated with these technologies is concentrated in off-farm actors, primarily in upstream stages, operating in oligopolistic markets controlled by large multinational firms working in public-private innovation networks. The adoption of ICTs and associated new technologies by Latin American agricultural producers is concentrated in large and medium-sized farms, which has increased rather than narrowed the digital divide and because of their uneven diffusion they have had little effect on the heterogeneities that have been historically present in the sector.

Some policy recommendations may be suggested driven from the above analysis.

Policies oriented to improve the access to and the diffusion of ICT technologies among regionally disperse farmers and small and medium size producers should take into account these heterogeneities, providing training courses and a more equal access to these technologies through public extension institutes.

Supporting and stimulating the collective organization of small and medium size agriculture producers (for instance in cooperatives), public-private partnerships and an adequate institutional support, are important policies for the democratization of power relations and asymmetric distribution of knowledge and benefits resulting form the dissemination of ICT inside value chains and networks.

Public policy should aim to build institutional framework, i.e. generate public spaces in which farmers can share information, software and search engines. These public spaces may function as disseminators of information and they allow populating large databases. For example, simulation models developed for early warning for a given crop can be extended to other contexts if relevant agronomic and agro-climatic information is available. Therefore, the creation of public spaces is key in the policy design.

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Kugler Norberto. Cattle producer
Ignacio Albornoz. Agriculture consultant, Brazil
Martín Irurueta. Expert on traceability, INTA, Argentina
Mascarini, Claudia. RIAN, INTA
Mendéz Andrés. Precision Agriculture , INTA Manfredi, Argentina
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Villalobos, Ruy. United Nation, IFAD, International consultant on agriculture projects and policies.

V. Principal barriers to the adoption of ICTs in agriculture and in rural areas

José Nagel

A. Introduction

Access to and use of information and communication technologies (ICTs) around the world have been raising exponentially over the last decade. Mobile telephony has seen the swiftest growth, with the number of cell phone subscribers increasing from 739 million in 2000 to 5.2 billion in 2010, followed by the Internet, for which the number of users jumped from 394 million in 2000 to 2.08 billion in 2010. Broadband use has also expanded significantly, from 1.1 subscribers per 100 inhabitants in 2005 to 13.6 in 2010 (ITU, 2010).

This process has been accompanied by a constant flow of innovations and changes in technologies and in modalities of use. Within a period of five years broadband has expanded, there has been a move to mobile telephony networks with convergent technologies (2G, 3G, and 4G), integrated mobile terminals have become available, and multiple applications and services have been generated. The individual and local storage of information has been superseded with the generation of service networks and applications that for the first time have made "cloud computing" a reality, supported by software, applications and Web servers and offering specific and differentiated services online. The result is a worldwide platform with unimagined possibilities for growth and impact (Mohsen, 2009).

Although the indicators reveal a gap between Latin America and the Caribbean, on one hand, and developed countries, the region has seen steady growth in ICT use. This is particularly the case with cell phones, where the gap with developed countries is narrowing: the subscription rate per 100 inhabitants in 2009 was 89, and in some countries it actually exceeds 100. Internet access has also seen sustained growth, rising from five users per 100 inhabitants in 2000 to 31 in 2010. These figures, of course, conceal internal discrepancies, which in most countries are very important, with great differences related to such variables as location, education level and income (ECLAC, 2010a).

It is the rural and agricultural sector that seems to be lagging furthest behind in incorporating ICTs into productive, social and cultural activity. Herein lays a challenge that should be a matter of concern if the region is to avoid widening the divide that generates new forms of exclusion and of economic and productive inefficiency.

This chapter offers an overview of the limitations on the adoption of ICTs in Latin American agriculture, highlighting traits and tendencies with respect to ICT access and adoption. It also examines the way countries are responding to the challenge of generalizing the information society in the agriculture sector and in rural areas, with particular attention to the situation of small farmers.

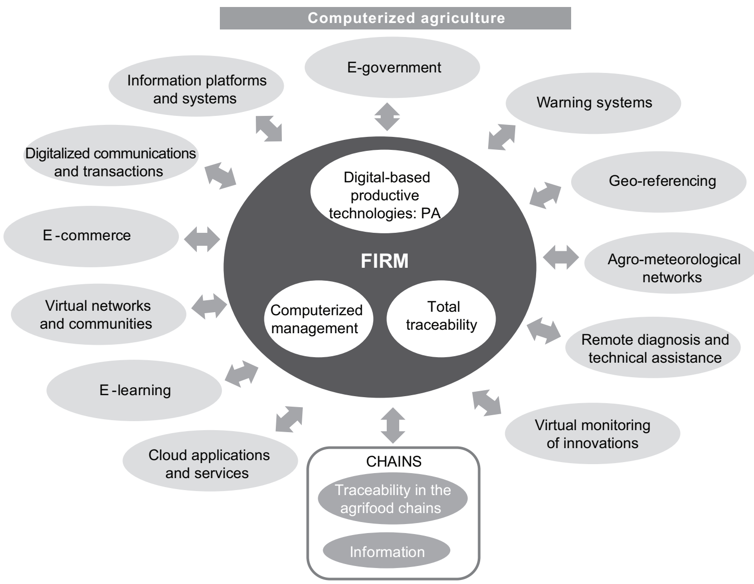
The term “ICTs” refers to those technologies arising from progress in computer science, the Internet, telecommunications and audiovisual technologies, including the recent processes of convergence. For the purposes of this study, the central focus is on the accessibility and use of computers, the Internet and cell phones and their social, economic and cultural effects

This chapter begins with an overview of the possibilities that ICTs offer for agriculture and rural development and then goes on to examine the barriers and limitations that impede the generalized use and adoption of these technologies by farmers. This is followed by a review of digital policies and strategies targeted at the rural and agricultural world, describing countries’ experiences and offering some suggestions concerning digital policies for the sector.

B. Adoption of ICTs in agriculture: from digital literacy to knowledge management

ICTs can make a powerful contribution to the competitiveness of agriculture and they can be applied in nearly all areas of management and production within firms and within the agrifood chains. Figure V.1 provides some examples of areas where ICTs can be useful in an agricultural enterprise, in the value chain, and in the peripheral systems. Some of these examples are also valid for rural areas in general, but the focus here is on agriculture.

Figure V.1
ICTs in the agricultural firm



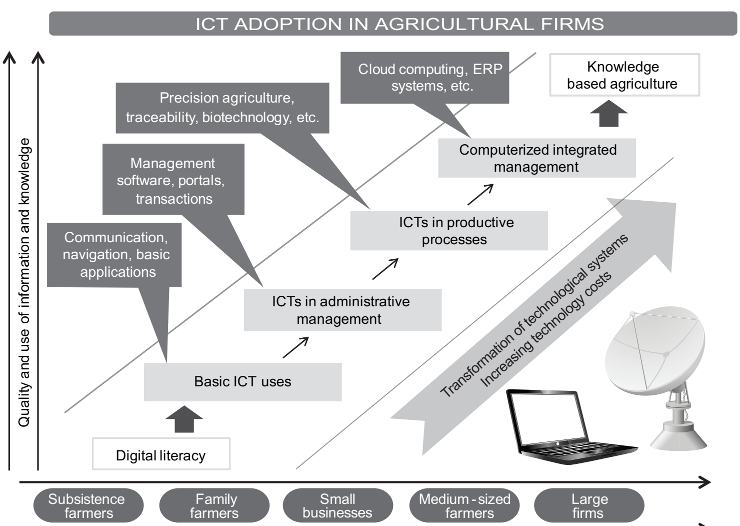
Source: Prepared by the author.

Introducing ICTs into the administrative and financial control of agricultural firms can enhance efficiency, reduce costs, and lead to sounder decisions. Similarly, digital-based productive technologies (precision agriculture, GPS) can contribute to the rational use of resources, higher profits, and greater productivity. The use of digital tools and instruments also has an impact on sustainability, as the rational management of inputs allows for less reliance on agrochemicals and contributes to the reduction of residues and the elimination of plant and animal diseases (Best, 2008).

Lastly, the adoption of ICTs is central to addressing the consequences of climate change. To this end, technologies must be developed that will allow the efficient use of irrigation and drainage, early warning systems, systems for combating new diseases, systems for managing droughts and climate information networks for farmers. This will involve teledetection, geo-referencing, sensors, monitors and technologies for remote, real-time data transmission and processing as the basis for information and knowledge systems that will support decision-making.

The adoption of ICTs by agricultural firms is a complex process, one that occurs in successive stages and is conditioned by the structural heterogeneity and stratification of farmers. Figure V.2 illustrates the stages of ICT adoption by farmers along a path of progressively more intensive use of information and knowledge. After a rudimentary phase of basic uses, ICTs are introduced professionally in administrative management, incorporating functional applications suited to administrative, economic and financial supervision. Normally, the incorporation of ICTs into production is a subsequent and more complex stage that requires greater investment. Finally, the comprehensive computerized management stage presupposes the incorporation of ERP ("enterprise resource planning") systems (which comprise all the subsystems), comprehensive traceability and intelligence systems and, to a still very limited extent, cloud computing (Nagel and Martinez, 2007).

Figure V.2
Stages of ICT adoption by farmers



Source: Prepared by the author

There seem to be incremental costs (and of course benefits) to the incorporation of ICTs, as the process moves toward stages of greater complexity. The basic uses require relatively few resources. The incorporation of management applications demands greater resources and, at more advanced stages, the introduction of ERP systems or precision agriculture involves significant investments that only larger and well-capitalized firms can afford.

In development strategies it is essential to consider the dual objectives of digital inclusion and increased competitiveness of firms. The heterogeneity of the farming population and the coexistence of firms of great diversity and level of development require strategies with activities ranging from digital literacy to complex instruments and applications. In turn, attention must be paid not only to digital development for firms but also to the peripheral systems, in order to have a virtual supply of instruments, applications and contents that will make knowledge-intensive agriculture possible.

C. Tendencies that encourage the adoption of ICTs in the region's agriculture

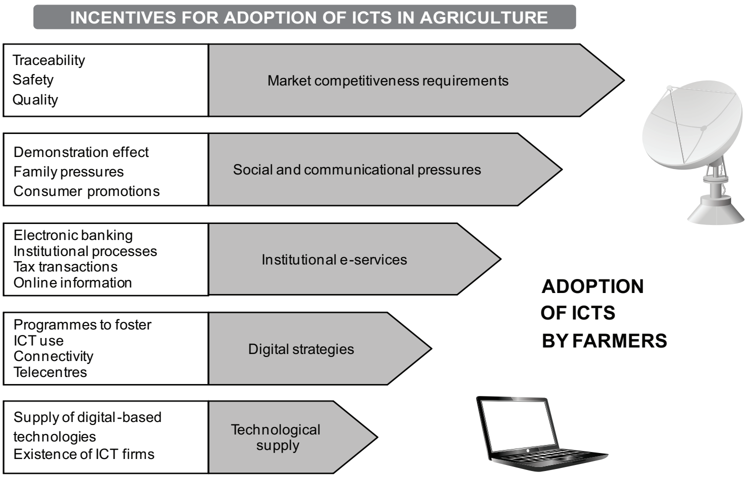
Figure V.3 provides an illustrative summary of the main fields in which pressures and incentives arise for adopting ICTs in Latin American agricultural businesses. Some of these factors, of course, also affect the rural population as a whole, but here the focus is on agriculture.

The greatest pressures on agricultural firms to adopt ICTs arise from the need to be competitive on markets (mainly external ones). Stiffer demands with respect to quality and safety are also appearing in local markets, as consumers begin to adopt patterns similar to those in markets in developed countries. This phenomenon has been encouraged by the expansion of the big supermarket chains which now dominate agrifood marketing and are setting the standards for agricultural products (Reardon, 2003).

Social and communicational pressures, generated within farmers' own families, consumer concerns, and the demonstration effects from other social sectors also encourage the adoption of ICTs. Studies show that farmers' wives and children are moving quickly to adopt ICTs. A study in the Dominican Republic found that 53% of the users of the Community

Access Centers (CAC) were women (Khelladi, 2008). Studies in Uruguay and Chile have also shown that women and daughters of farm families are a factor of assistance and intermediation (proxy user) with the digital world (CENDEC-IPA, 2007).

Figure V.3
Incentives to ICT adoption in agriculture



Source: Prepared by the author

In 2010, 11 countries of Latin America and the Caribbean were implementing programmes to endow schools and teachers with computers and broadband Internet and in some cases were donating personal computers to every student (CEPAL, 2010). The beneficiaries of these initiatives are located for the most part in rural areas and the majority of the students belong to farm families. Despite inter-country differences (Uruguay has one computer for each student, Honduras has one computer for every 137 students), and despite home Internet access is very uneven, these initiatives are for the first time bringing computing to rural families and introducing a very powerful demonstration factor for farmers.

At least nine countries are pursuing telemedicine programmes offering remote diagnosis and primary care in rural medical offices, which are frequently one of the few points of connectivity available to communities.

The introduction of ICTs in a service that is so important to families that also constitutes a powerful vehicle for demonstrating the usefulness of the new technologies, and it is having a demonstration effect that also influences attitudes towards ICTs (Hernandez, 2010).

For the most part farmers are not immune to consumption pressures, except perhaps in highly isolated geographic areas. Access to radio and television generates communicational flows that tend to standardize consumer aspirations, particularly among the young. Electronic goods, even if they are beyond the means of the majority, infiltrate the field of vision and aspirations of rural dwellers and farmers.

As public and private institutions make electronic transactions more available, pressure is mounting on farmers to join the "information world". During the last five years, private and public institutions as well as governments have stepped-up the process of digitalizing transactions and procedures. Electronic banking services have become almost universal and an increasingly broad range of products can now be purchased via the Internet. Although most farmers still lack access to these instruments, this practice is beginning to take root in the more advanced sectors.

Electronic government has also been expanding, and nearly all countries have implemented some system for handling paperwork online; for example, 11 countries allow transactions to be conducted in this manner and some, such as Colombia and Mexico, have a "single window" to facilitate citizen access (ECLAC, 2010). The growth in online transactions offered by the public system has been significant in some cases, such as Chile, where the number of government online procedures rose from 12 in 2001 to 476 in 2009 (SDD, 2010). Although various studies (FIA, 2009a; CENDEC-IPA, 2007) show that farmers still rely for the most part on face-to-face transactions and processes and information sources, the existence of the digital option is exerting pressure on them to make greater use of ICTs in their personal and productive activities.

As discussed later in this chapter, the various efforts that public and private institutions as well as NGOs are making to promote digital development are also providing an incentive for farmers to adopt ICTs.

D. The digital divide in rural sectors and in agriculture

As a counterweight to the set of factors that are promoting the expansion of ICTs, there are still some persistent gaps in access to and use of these technologies in rural sectors and among farmers of the region. The following graphs, based for the most part on household surveys, illustrate the main trends relating to ICT access and use in rural and farming households. "Farming households" are understood here as those where agriculture is the principal occupation of the head of the household.

1. The access gap

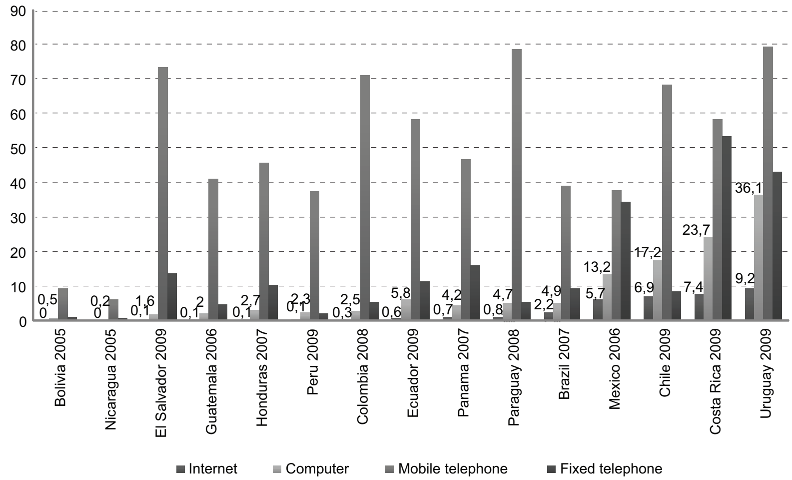
The high penetration rate of mobile telephony in rural sectors is a feature common to all countries of the region (see figure V.4). In some of them, more than half of the rural population has a cell phone, and in four countries this rate exceeds 70%. This has not only brought an improvement in terms of communication, but it has also opened a bridge to the information society, and as new convergent technologies are developed and offeed a powerful tool for ICT expansion strategies, with the obvious limitations with respect to more complex operations or applications.

On the other hand, rates of access to computers and to the Internet are generally very low, although differentiated. The computer seems to have made its way into rural households, regardless of connectivity possibilities. This could be explained by the needs or demands of other household members, particularly the children. Studies in some countries show that computers are more likely to be found in households with children between 6 and 18 years of age (UAH, 2009). In any case, having a computer without the Internet, while obviously a limitation, nevertheless opens the possibility of using local applications and becoming familiar with the digital world.

There are some important differences among countries, with one group (Uruguay, Costa Rica, Chile, Mexico and Brazil) showing clearly higher indicators. These countries seem to have made special efforts to ensure connectivity and community access points. In all cases, however, the internal gap between the urban and rural sectors in each country is very wide. Even in countries where this gap is less significant, urban Internet access is three or four times as high as rural access, and in the majority of countries it is 10 times as high or more.

Figure V.4

Latin America (15 countries): fixed and mobile telephone, computer and Internet access in rural households

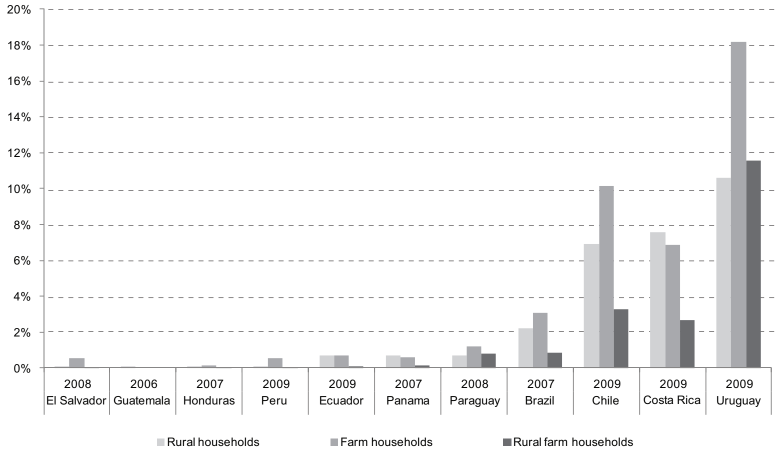


Source: OSILAC, based on household surveys

Against this backdrop, farmers' access to Internet and computers, although higher than the average for rural households, is also very low and reveals differences between farmers living in urban and rural areas. Households headed by farmers have low Internet access rates but they are generally higher than those for the rural population (see figure V.5). This difference reflects that farmers living in urban areas (usually medium-sized towns) have greater possibilities for connectivity through community access points.

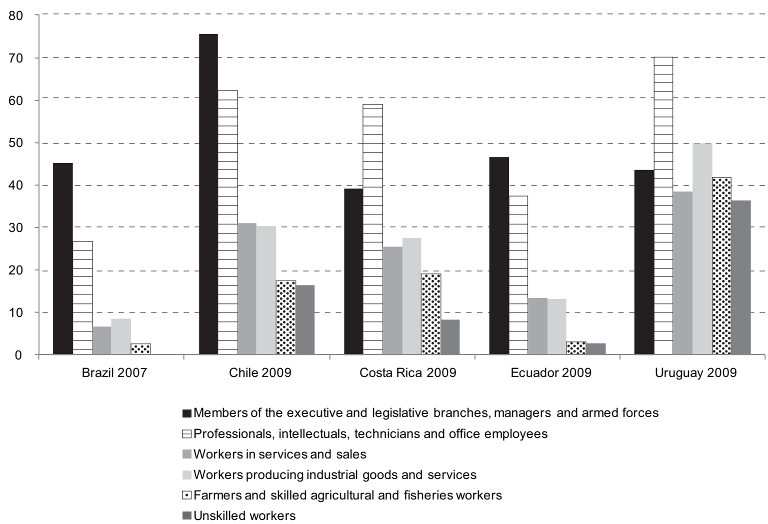
ICT access indicators for farmers are lower than for other occupational categories, including rural nonfarm activities. Farmers living in rural areas face disadvantages compared to other rural inhabitants who are engaged in non-agricultural work more closely linked to the world of services or commerce. In fact, farmers rank above only unskilled workers in terms of Internet access in rural areas (see figure V.6). Nevertheless, in the more advanced countries (Costa Rica, Mexico, Brazil, Chile and Uruguay), Internet access in rural areas has grown steadily in recent years, doubling or even quadrupling both in rural households and in farm households.

Figure V.5
Internet access in rural and farm households



Source: OSILAC, based on household surveys .

Figure V.6
Internet access in rural households, by occupational category of head household

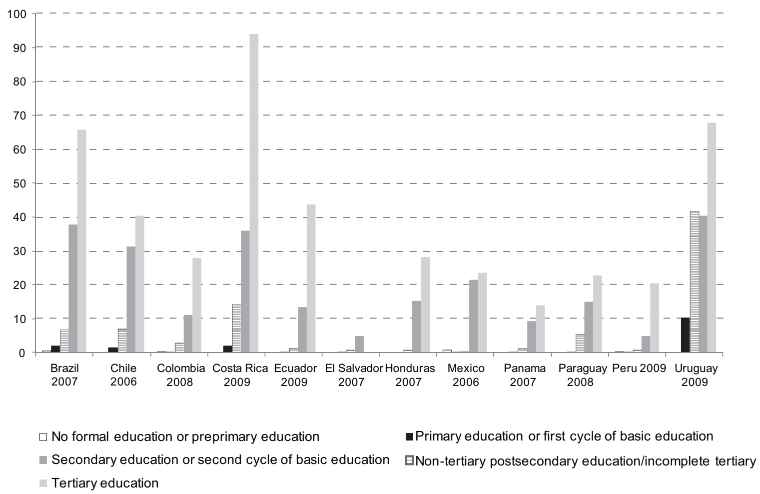


Source: OSILAC, based on household surveys

The main constraint on the expansion of ICT use is level of education. In the case of farmers in Latin America, there is a clear relationship in all countries between the two variables, with Internet access and use rising with higher levels of schooling. In particular, there is a notable jump in access at the secondary education level (Nagel and Martinez, 2007). Yet, for a given education level, the number of farmers who can access the Internet will vary according to the possibilities offered in each country. Thus, the proportion of farmers with tertiary education who access the Internet in Uruguay is several times higher than that in Paraguay, Peru or Panama (see figure V.7). This would seem to indicate that, while education level is fundamental in enabling ICT access, there are other conditioning factors in play (availability of connectivity, points of access, etc.).

Figure V.7

Internet access by level of education in farm households

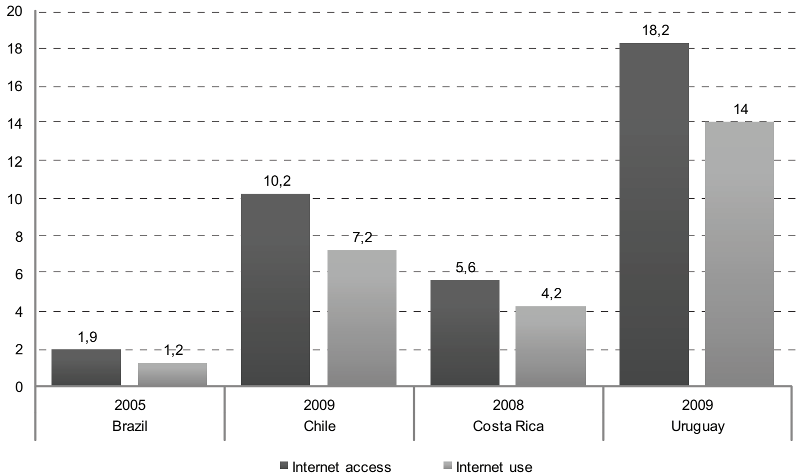


Source: OSILAC, based on household surveys

2. Gaps in use and adoption

Having access to the Internet does not necessarily guarantee that farmers will use it. In most cases, farmers consistently make less use of the Internet than they could. This is confirmed by research showing that, even if they have a computer at home or at work, farmers do not use it or they do so via a proxy user, who may be a son or daughter (Nagel, 2005; FIA, 2009a). Figure V.8 shows the difference between Internet access and use in farming households for Latin American countries that have such information available.

Figure V.8
Internet access in farm families and Internet use by farmers



Source: OSILAC, based on household surveys

The likelihood of ICT use varies with the size of the farm and the category of those engaged in agriculture. Various sources on the relationship between farm size and computer and Internet use show that such use is very low among small-scale farmers and rises systematically as the size of the farm increases. ECLAC data, based on the agricultural censuses of Brazil and Chile, show that ICT use in agriculture increases consistently with farm size, with differences of up to 10 times between farms smaller than 5 ha and those of 500 ha and more. This same tendency emerges from data on agricultural occupation categories, where the most notable difference is between "employers" (i.e. business owners with some capacity to hire labor) and other categories, including "own account" workers, which covers a great many small farmers engaged in subsistence agriculture.

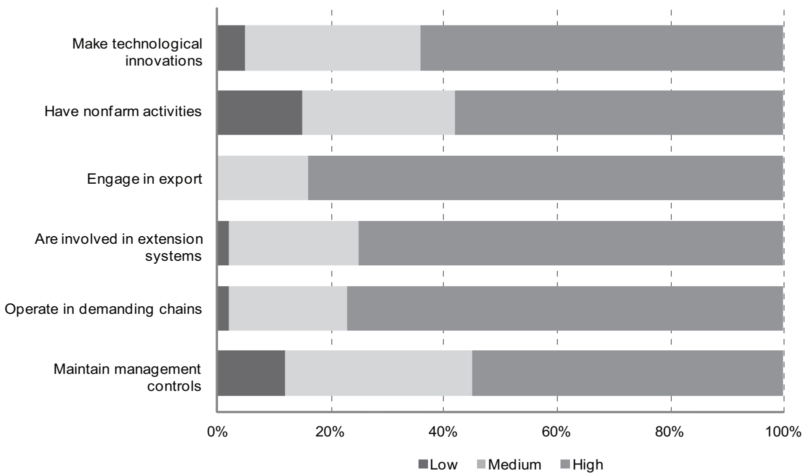
The probability of computer and Internet use also seems to be higher among farmers engaged in export and agro-industrial activities, and located in chains that are demanding in terms of information and knowledge. A Chilean study showed that only 4.3% of grain growers were using the computer, and this proportion rose to 35.5% among fruit producers, and to 72.7% among producers of honey for export (FIA, 2009a). The same study indicated that —at least in certain cases— producers who have another paid activity make greater use of ICT: for them, Internet use is up to 60% higher than among persons confined strictly to agriculture

(FIA, 2009a). This finding is reinforced by the perceptions of agricultural experts in countries of the region (see figure V.9).

Against this general backdrop, however, situations can be identified in which groups of small farmers make greater use of ICT than the averages would indicate. Various studies show that groups of farmers who are better integrated into markets, who participate in support programmes, and who live in areas targeted by special activities have greater levels of ICT use. This can be seen in productive development projects associated with ICT instruments in areas of the Plurinational State of Bolivia that have introduced telecentres (Suarez Rodas, 2008) and in some pilot experiments involving rural wireless networks in Uruguay (Grampin, 2011).

Figure V.9

Probability of ICT use by farmers, by type of activities, as perceived by key agents



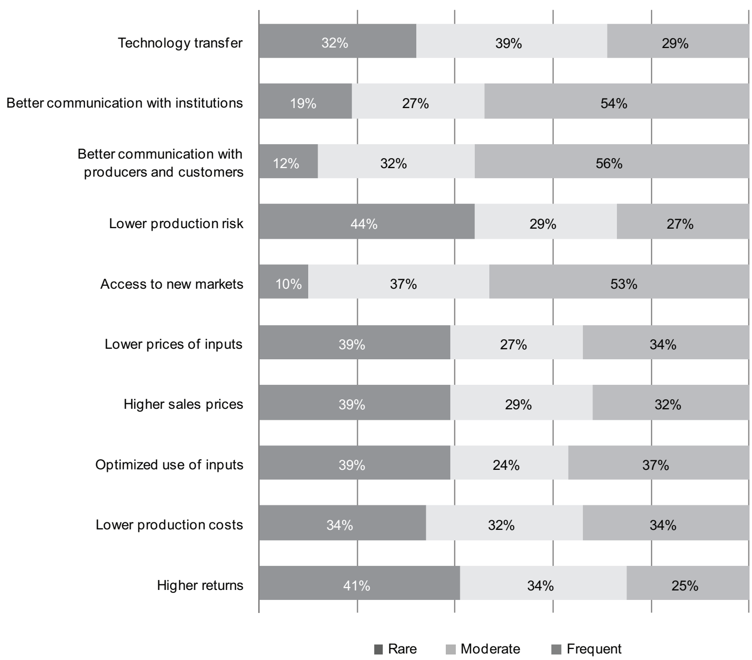
Source: ECLAC survey of agricultural specialists

Farmers use the Internet mainly to search information and for communication, and very rarely to perform transactions. There is almost no transactional use among farmers: only in Uruguay and Costa Rica has electronic banking made any headway among farmers as an Internet use. Only 1% uses the Internet for purchasing, contracting, or any type of electronic commerce. Climatic information and prices seem to be the main areas of interest in farmers' information searches (FIA, 2009a).

There is very little use of ICTs in business management. Uruguayan studies of livestock producers with medium-sized operations show that 71% of producers keep records and controls in paper notebooks and only 15% use a computer (CENDEC-IPA, 2007). Another study of small farming businesses in Chile, found that no more than 25% of producers were using any spreadsheet to keep records (FIA, 2009a). Executives, professionals and technicians working in agricultural firms or providing advisory services to farmers are among the greatest users of the new technologies. They often serve as intermediaries between farmers and these technologies and they have the capacity to be active agents in the dissemination of ICT use (FIA, 2008).

Lastly, the greatest perceived impacts from the use of ICT among farmers have to do with improvement in communications and access to new markets and, to a lesser degree, with optimizing the use of inputs and reducing production costs (see figure V.10).

Figure V.10
Perceived impacts from ICT use in agriculture

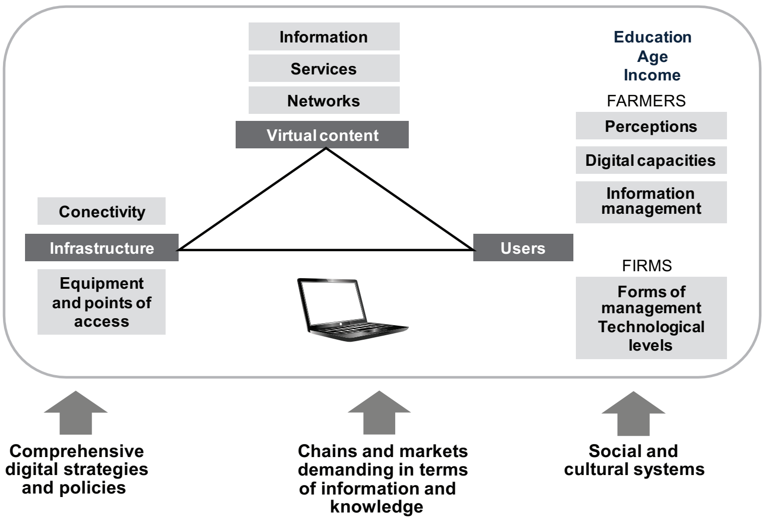


Source: ECLAC survey of agricultural specialists

E. Barriers and constraints on farmers' access to ICTs

The principal factors placing barriers and constraints on farmers' access to computers and the Internet are shown in figure V.11. These factors have different weightings: some are central to ICT access (connectivity, education level) while others are secondary. Government policies, markets and local social systems and networks can also raise or reduce barriers to ICT access. Experts consulted in various countries cited connectivity and education level as the greatest barriers, followed by high costs and farmers' perception that ICTs are not very useful.

Figure V.11
Barriers and constraints affecting farmers' ICT access



Source: Prepared by the author

1. Barriers and constraints with respect to users

a. Education

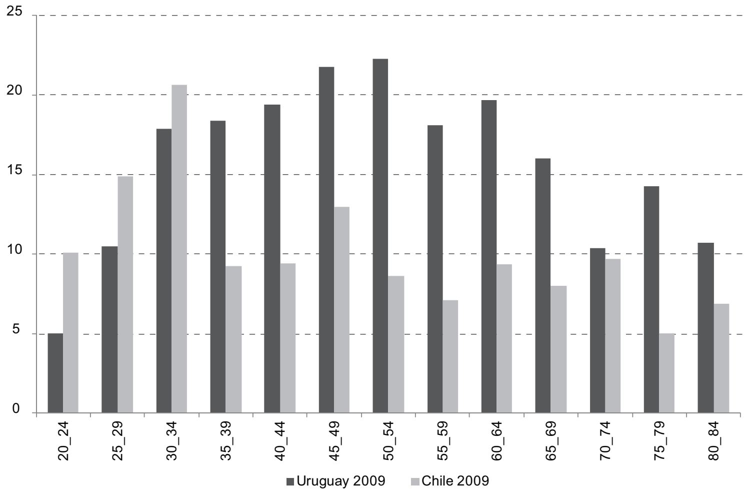
With rare exceptions, farmers in Latin America have very little schooling. For example, 28% of Mexican farmers had no schooling in 2007, and 54.9% had only a basic education (FIRA, 2009); in Paraguay, 82.8% of producers had basic education or less according to the 2008 Census. There is little possibility of influencing this factor in the short run, as the expansion of education systems has effects only over the medium and long term and, of course, with the generational shift. Consequently, educational constraints must be treated as a parameter when planning immediate strategies for digital expansion and the deficits will need to be offset with training, information and motivation activities.

b. Age

In countries for which data are available, the average farmer's age is over 50 years. According to some studies and the opinions of key informants, being older can be an obstacle to the adoption of ICTs. Data on ICT use among the rural population confirm these assertions. For example, a study in the Dominican Republic on the Collective ICT Access Centers (CACT) found that 81% of users were between the ages of 15 and 39 years (Khedalli, 2008). In Colombia, 61% of COMPARTEL telecentre users are under 24 years (CEDE, 2007). In Chile, a study on ICT use among INDAP beneficiaries showed that Internet use was twice as high among farmers under 30 than among older farmers (Nagel, 2005).

Yet available household statistics do not reveal such a close association between age and ICT adoption, and there are also great differences among countries. It would appear that differences in ICT adoption can be better explained by the educational levels of different age groups. In Uruguay, for example, where educational differences between age groups are smaller, thanks to generalized early education, the distribution curve of ICT access is flatter, and access is greater among farmers in the 50-54 age group. In Chile, by contrast, where education is less universal in rural areas and older generations have less schooling, the rate of ICT access reaches its peak among 30-year-old farmers (see figure V.12).

Figure V.12
Farmers´s access to Internet, by age groups



Source: OSILAC and CASEN Chile

c. Income versus costs of ICTs

There are studies to show that the high price of broadband service is a barrier for families in the lower income quintiles, and that strategies for lowering those prices can be important in enlisting new users of ICTs. Data from 13 Latin American countries show that Internet access among households in the highest income quintile is more than 37 times that for the poorest quintile (Jordan, 2010). In Latin America, agricultural households are among the poorest population segments (Rodriguez and Meneses, 2010).

Low incomes contrast with the high costs of broadband service in the region. Rates vary among countries (US$50 in Uruguay, US$170 in Ecuador, US$325 in the Plurinational State of Bolivia) but studies show that the average tariff for broadband plans in Latin America (US$125) is 2.5 times the OECD average. Moreover, the cheapest plan in OECD countries costs only 0.3% of the median household income, compared to 5% in Latin American countries (Galperin, 2010).

In this context, various research studies highlight the difficulties that farmers face in paying for ICT access. An ECLAC study found that 80% of rural households in Colombia and 60% in Brazil are not in a position to pay the current price for broadband service (Galperin 2010). Farmers are well aware of this. A survey in Mexico showed that 56% of those interviewed cited low income as the main reason for not having a computer (ITU, 2009). The same cause is cited in the Brazil study, where 48% of persons surveyed pointed to the same impediment (Galperin 2010).

d. Attitudes and perceptions

The cultural model of the knowledge society in Latin America is essentially an urban invention that is gradually infiltrating the countryside. Consequently, digital expansion often seems to collide with cultural and social barriers, particularly in the case of older persons for whom the new technological world is not one in which they can easily be inserted.

Many responses from experts interviewed show that the enthusiasm of farmers for the computer and the Internet is dampened by the perception that these instruments are of no use in the tasks they are performing, and that the return on investment in ICTs is low. For many farmers, moreover, their self-image conspires against any motivation to work with new technologies. They frequently see themselves as incapable of handling precise and complex instruments, which they assume require levels of preparation and fine motor skills that they have not achieved (Bossio, 2005; Nagel, 2005).

e. Digital skills

Given the education levels of most farmers and the nature of their work, it is not surprising that they lack digital skills and abilities. Digital training activities typically focus on developing skills for working with the computer and its basic applications to master text processors, web browsers, and spreadsheets. For various reasons this training does not normally move on to develop skills for identifying, assessing and using information. These are operations that are essential for applying ICTs to agricultural management, but farmers are not accustomed to performing them. Nor this training includes the management of interactive applications and instruments that would facilitate integration into virtual communities where the possibilities of the Internet can be more fully utilized. These shortcomings are important barriers to seizing the potential of ICTs.

2. Constraints related to farm management methods

Many farmers do not maintain management controls over their farms, or if they do so, thet do it in a simplistic way, merely recording elementary data for making rough calculations of the return on their business. Farmers do so in many countries because they are not obliged to keep accounts and they rely on "presumed income" systems that do not require detailed records. There is no pressure on them, then, to introduce efficient controls and this reinforces farmers' perception that computers and the Internet are not very useful. In the case of farmers who are integrated into modern markets and are subject to tax audit, they will generally entrust the management supervision of their business to third parties, to professionals, or to their own children (FIA, 2009a).

Many informants indicated that farmers are beginning to feel the need to adopt ICTs as they come to participate in programmes such as Best Agricultural Practices or Livestock Traceability, which require record-keeping at all stages of the productive process under penalty of losing their access to markets, credit, inputs, networks and support services.

3. Connectivity as a central barrier

Making broadband universally available is a challenge that countries of the region have undertaken to address, in order to bring all sectors into the information and knowledge society (ECLAC, 2010). Yet, this objective is far from being achieved, and there are still significant gaps in countries of the region. These have to do not only with costs, as discussed above, but also with connection possibilities and the quality of service.

a. Connection availability

The availability of broadband connectivity in countries of the region tends to be concentrated essentially in the cities, and to a lesser extent in towns of the interior, with little coverage in rural areas. As a result, most farmers do not have acces to the Internet. This situation can be blamed in part on market considerations: because of such factors as population dispersal, low incomes, and lack of incentives to incorporate ICTs, rural areas do not offer the critical mass of potential customers needed to make the service profitable for providers.

In an attempt to deal with this reality, communities have experimented with local Wi-Fi networks, setting up self-managed systems to serve a specific clientele belonging to a local community or group of producers (Bossio, 2005). These normally require a commercial firm to provide the connectivity, which is distributed by the network to a set of users. The experiments have been limited as to coverage, extension and bandwidth, but they represent possible solutions in isolated areas or those where the market is unattractive to commercial firms (Siochru, 2009).

The provision of broadband for rural areas is a matter of government concern today in most countries of the region, which are seeking to resolve the issue through ambitious programmes targeted at rural communities. These may entail various forms of subsidized delivery, either through a government enterprise (as in Uruguay and Costa Rica) or under contract with private providers (as in Chile and Brazil).

Mobile broadband has the potential for development in rural areas and could do much to overcome the connectivity deficit as prepayment facilities become more common. The widespread use of cell phones in rural areas offers an interesting platform for such development. Yet, at the present time short supply and high prices make it premature to proclaim this as a mass solution for rural populations and farmers.

b. Connection quality

The digital divide is a moving target, in which the emphasis is shifting from coverage to quality of access. Quality has to do with the connection's capacity to allow users to take full advantage of the Web's potential. This requires reliable continuity of the signal and bandwidths with the speed and efficiency needed to handle relatively complex contents and operations and to allow information, image and voice transmission adequate for advanced business management.

There are some significant differences between countries in the quality of broadband services, which range from a maximum of 20 to 30 Mbps in Argentina, Brazil and Chile to 2 Mbps in The Bolivarian Republic of Venezuela, El Salvador, Nicaragua and Cuba. In most countries, more than 50% of users have download speeds no higher than 1 Mbps and upload speeds of 256 Kbps. These speeds are insufficient for anything more than basic communication (Jordan, 2010). For example, bandwidths below 2 Mbps make it difficult to operate precision agriculture systems, to conduct remote diagnostics, to compile and make use of yield maps, or to support videoconferencing.

4. Terminals and points of access

a. Terminals

Connectivity alone is not enough if there are no terminals for accessing and taking advantage of all the possibilities of ICTs. It has been noted that farmers' access to terminals is high when it comes to telephones and very low when it comes to computers and their accessories. In the latter case, lower user rates are related both to the lack of connectivity, which discourages use, and to prices, which are still beyond the reach of most low-income groups. The average price of a medium-capacity computer in Latin America is still around 400 to 500 dollars. Of no less importance are the operating and support costs of the equipment, which include the connection as well as maintenance and technical assistance. These costs are normally high and the services are hard to find in small rural towns.

Convergent mobile terminals are now spreading rapidly in urban areas and could in principle represent a solution for the lack of fixed broadband connectivity, but they are unlikely to be widely adopted without lower prices for the equipment and prepayment plans with tariffs compatible with farm incomes.

b. Shared points of access

Shared Access Centers, in the form of telecentres or commercial cybercafés, are an important mechanism for providing ICT access for rural populations. For farmers who use ICTs these facilities are, after the home, the favored place for accessing the Internet. Telecentres add a dimension of training for knowledge management, and this has made them a valuable element in democratizing ICTs. Nevertheless, they need a partner that will ensure their financing and continuity (Caicedo 2008).

There is some evidence that farmers are reluctant to visit telecentres. One assessment of telecentres under the COMPARTEL-INTERNET SOCIAL programme in Colombia showed that farmers were making less use of telecentres than were any other economic group (CEDE, 2007). Another assessment of telecentres in Peru found that most of the users were young people from the middle-income strata of their communities (Bossio, 2008). Yet, experience in some training institutions seems to show that this resistance can be overcome by forming homogeneous groups in which farmers feel they are among their peers (Nagel, 2005a).

5. Factors relating to the competitive environment

a. Chains and markets undemanding in terms of information and knowledge

Markets are a fundamental factor for encouraging or discouraging the use of ICTs by farmers. Traditional markets, confined to local demand, are not very competitive, they are generally oligopolistic, and they impose few quality requirements, and consequently they exert little pressure for the use of information and knowledge. By contrast, dynamic and competitive markets oblige farmers to boost their efficiency and improve their controls, for which they need digital tools. For example, growers of traditional grape varieties for local consumption have much lower ICT use indicators than do producers of honey for export (FIA, 2007).

b. Social and cultural systems at the margins of the knowledge society

The social systems and networks in which farmers are immersed at the local level do not encourage the use of information and knowledge as an instrument for personal life or for work and production. This means that the abstract world of communication falls outside the frame of reference in the cultural norms governing individuals' conduct.

c. Limited digital strategies

Digital development strategies often lack a comprehensive vision to generate effective incentives for farmers to adopt ICTs. Many of them focus exclusively on connectivity or basic digital literacy, and do not include any vision for addressing barriers and constraints in a coordinated manner. Moreover, as discussed below, agriculture does not seem to be a priority sector in national strategies for digital development. Nor do the sector policies of the line ministries, with a few exceptions, include any efforts at digital development. Moreover, extension services usually do not include ICTs among their communication methodologies and their training for farmers.

6. Farmers' information needs and the availability of contents on the web

At all stages of the value chain, farmers need informational inputs that can be provided through the use of ICTs. Studies have shown that farmers prefer face-to-face channels for obtaining this information, relying on persons they trust (technicians, support professionals) and to a lesser degree on written information. These messages generally come from official support institutions and, increasingly, from agro-industrial and marketing firms with which farmers have forged links (FIA, 2009; Nagel and Martinez, 2007). As to the characteristics of the information, various informants consulted report that farmers have three demands: information must be up to date, it must be local, and it must be available at simple and user-friendly portals.

From this perspective, there are two dimensions to the issue of the supply of and demand for virtual information. On one hand, farmers still have trouble transferring their demands for information from the in-person and hardcopy formats to digital platforms. On the other hand, there are questions as to the degree to which the supply of digital information is adapted to farmers' real needs and characteristics.

It is important to distinguish between the supply of information, services, software and social interaction. The information supply could be a constraint or barrier if its form or content is not suited to farmers' needs and characteristics. Some studies have shown that, in the case of family farmers, digital contents are frequently inadequate and do not meet their immediate needs (Bossio, 2005). Farmers also complain that the scattering of information sources is a problem for them and in some cases they cite the failure to update the information delivered at specialized portals. An additional issue of importance, particularly for family farmers with low education levels, has to do with the navigational difficulties of some portals.

The lack of specialized services (online processing, submission of projects via digital channels, financial interactions) may pose a problem for the more sophisticated farmers who wish to build ICTs into their activities. The lack of virtual networks for social interaction also conspires against the full use and circulation of information, and feedback between farmers. Given their characteristics, tools such as Facebook or Twitter are not sufficient: what farmers need is interactive instruments by which they can integrate themselves into specific virtual communities. Experiments such as the RURALCAT in Catalonia and *YoAgricultor* in Chile demonstrate the possibilities that this channel can hold for producers.

F. Policies and experience with digital development for agriculture and the rural sector

There is a spontaneous trend towards the generalized use of ICTs in the region, and this includes the agriculture sector. The expansion of ICTs does not seem to depend on public policies but is rather a social, cultural and market phenomenon with its own dynamics. The statistics provided above reveal an increase in Internet access and use among rural and farming families, and growing participation by the younger generations in the digital world. Rising education levels also work in favor of this spontaneous spread of ICTs.

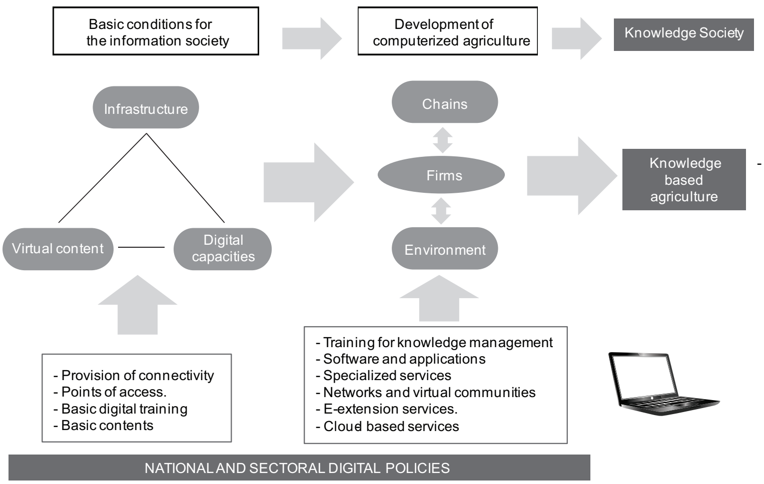
Digital development efforts are having a specific impact on the spread of ICTs in agriculture and in rural areas. Public policies for the regulation and development of ICTs and the efforts of private agencies seem to be having a positive impact in terms of expanding their access and use. For example, although there is a correlation between levels of economic development and digital development, at comparable levels of per capita income some countries have achieved greater digital development than others. This could be explained by greater awareness of the issue and by the existence of policies that have encouraged digital development (Guerra, 2010).

There is also evidence that the provision of connectivity leads to an increase in computer and Internet use. For example, the fact that Uruguayan farmers are now making greater use of computers and the Internet may reflect not only their education levels but also the existence of a network of infocentres. The same tendency appears in the wireless networks installed in Caternu in Chile, where the provision of connectivity boosted the adoption of ICTs significantly (FIA, 2010b).

Experience also shows that ICT training programmes can have a positive impact on farmers. An evaluation of TICBOLIVIA shows that between 2003 and 2007, some 155,000 farmers began to use ICTs as a result of the programme (Suarez, 2008). Making ICT promotion programmes more efficient and broadening their coverage, then, can bring real benefits to rural populations and farmers.

Policies must include general measures to improve ICT access in rural areas, along with specific strategies to foster their use and adoption by farmers. This implies strategies for providing infrastructure, access points, digital training and contents production, along with incentives to integrate ICTs into the technological systems of firms, agrifood chains, and the competitiveness environment, all with a view to developing knowledge-based agriculture. Figure V.13 shows the scope of action of digital policies for rural sectors and agriculture.

Figure V.13
Fields of action of digital policies for agriculture



Source: Prepared by the author.

Strategies to foster ICTs require sectoral efforts as well as broader policies of digital regulation and expansion. A key factor here is to ensure articulation between the sector authority and the national digital development agencies, as some measures exceed sector bounds. On the other hand, having national strategies in place does not obviate the need to adopt specific strategies for agriculture.

Given the speed at which digital technology is evolving, it is difficult to define long-term policies. Yet it is essential to go beyond immediate actions and to identify broader strategies for introducing ICTs into technological systems and for working on cultural and educational factors that are slow to change.

The heterogeneity of the farming population requires differentiated strategies for fostering ICTs in order to avoid widening the domestic digital divide. The fact that farmers have different conditions, resources, education levels and technological habits means that strategies to promote the use of ICTs in management and production must necessarily be differentiated both in their objectives and in their instruments.

G. ICTs, agriculture and rural considerations in national digital agendas

Several countries in the region have formulated digital agendas to address the issue of access to the information society. Those agendas reveal, to varying degrees, little concern for the digital inclusion of rural sectors and for the adoption of ICTs in agriculture (see table V.1). For example, it is interesting to note that prior to 2011 Peru was the only country to include any reference to agriculture in its national strategy. Uruguay and Colombia did so for the first time in the new versions published in 2011.

Table V.1

Inclusion of rural and agriculture dispositions in national digital agendas

Country	Name of strategy	Mention of rural connectivity and infrastructure	Mention of ICT use in rural areas	Actions proposed in agriculture
Argentina	Digital Agenda Strategy	No	Yes	No
Bolivia (Plurinational State of)	National Digital Inclusion Plan 2007-2010	Yes	Yes	No
Colombia	Vive Digital 2011	Yes	No	Yes
Costa Rica	Digital Strategy	Yes	No	No
Chile	Digital Action Plan 2008-2010	Yes	No	No
Ecuador	National Connectivity Agenda	Yes	No	No
Guatemala	National Agenda for the Information and Knowledge Society	Yes	Yes	No
El Salvador	ePaís programme	No	No	No
Mexico	National Digital Agenda 2011	No	No	No
Panama	Strategic Digital Agenda 2010	No	No	No
Peru	Digital Agenda	Yes	Yes	Yes
Uruguay	Digital Agenda 2011-2015	Yes	No	Yes
Venezuela (Bolivarian Republic of)	National Plan for Telecommunications, Informatics and Postal Services 2007-2013	Yes	No	No

Source: Prepared by the author.

Note: Brazil has no single document setting out a national strategy. However, it is implementing the National Broadband Plan which calls for specific measures to provide connectivity in rural areas.

A review of the content of these agendas suggests the following conclusions:

- Most of the agendas treat ICTs as instruments for social inclusion and equity. The agendas give priority to ICT access as a right and they stress the role of ICTs as instruments for social inclusion and participation. There is less emphasis on competitiveness and productive development, although this is quite important in some cases (Chile, Costa Rica, and Panama).

- All digital agendas include infrastructure and connectivity for universalizing access to ICTs, and most refer specifically to rural sectors. Consistent with the social inclusion focus, the goal of extending connectivity to rural sectors seems to be a priority. In the Plurinational State of Bolivia, Peru and Guatemala the rural priority is especially evident. In the digitally more advanced countries, such as Brazil and Chile, this priority is evident in specific plans and in financing for expanding broadband to rural localities.

- In few cases there are any specific actions proposed to foster the adoption of ICTs in agriculture. Nor, in general, have any mechanisms been defined for articulating digital policies within the sector or for integrating the actions of the various government institutions involved in agriculture. The exception is Chile, where the Ministry of Agriculture has established a “rural ICTs roundtable” and has prepared a roadmap to guide and coordinate the efforts of sector institutions. More recently, Costa Rica has also established a public-private ICT roundtable for bringing together the demands of the agricultural sector with the capacities of the local software sector.

- The specific actions taken by agriculture ministries and institutions suggest the existence of some underlying priorities. The central concerns of the ministries have been to provide agricultural information and to develop some basic services at institutional portals, leaving the provision of connectivity and access points to the entities responsible for digital development.

- Some countries have institutions that have taken the lead in digital development for agriculture. In several countries, it is the national agricultural research institutions (INIAs) that are driving the introduction of ICTs in agricultural firms and chains. Normally they do this in the context of specific and targeted research projects. In Argentina, INTA has taken the lead in at least two fields: precision agriculture and e-learning for agriculture. In Chile, as part of its agricultural innovation strategy, FIA has taken the lead by conducting studies and experiments and overseeing institutional coordination. A special case is EMBRAPA in Brazil, which has taken the lead not only at the national level but also with other countries in the Americas and Africa.

- Networks supported by international agencies have been a significant factor of motivation on the ICTs issue. Coordination bodies such as PROCISUR, PROCIANDINO and FORAGRO have played a role in generating knowledge and promoting ICTs in relation to technological development and agricultural innovation. Specialized bodies such as SICALC and projects such as FODEPAL and E-agriculture, supported by IICA and FAO, are also moving the issue forward in various countries.

- Digital strategies have not been coordinated with extension services and productive development systems. The generalized perception is that there is little or no articulation and this poses a problem, considering that ICTs co-evolve with technological systems and their successful appropriation is linked to such articulation.

- There is a generalized perception that digital strategies have contributed, but not as much as hoped, to increasing farmers' use of ICTs. Only 5% of the specialists consulted consider that digital strategies have been fully successful, while 50% think their impact has been modest, and 45% say they have not produced the expected outcomes.

H. Experiments for fostering ICTs in small farming and the rural sector

Public and private institutions have responded in two ways to the challenge of expanding the use of ICT in agriculture. Some have tended to address the agriculture sector or rural areas as a whole, without differentiating among types and strata of farmers. The assumption is that small farmers will benefit from these policies simply because they are part of the sector and most of them present huge digital deficits. In other cases, programmes have been targeted at small farmers in an effort to eliminate the barriers that prevent them from adopting ICTs. These approaches are rarer and are generally implemented by private entities, universities or international agencies.

Experiments for fostering ICTs in agriculture have originated in three sectors: public institutions, nongovernment entities (NGOs, universities, foundations, international agencies) and agricultural organizations and businesses. In quantitative terms, the most significant activities are those of public institutions, implemented in the context of government policies for digital extension or as the result of sector initiatives.

The actions of nongovernmental entities cover a very broad range of activities (digital literacy, connectivity, information systems, virtual networks, integration of ICTs in chains, climatic networks, precision agriculture, etc.). Nearly all are of small scale, but qualitatively of great importance (PROTIC, 2011).

There is also a range of projects implemented by farmers' organizations, rural communities, and agricultural businesses. Generally speaking, the activities of organizations and communities focus on social inclusion, while those sponsored by businesses emphasize technological innovation for competitiveness.

1. Connectivity and access points

Of particular interest here are the efforts that various countries have made to bring broadband to rural areas. To a greater or lesser degree, nearly all countries are striving to provide connectivity for rural areas and consequently for farmers, who are the most significant group of residents in these areas. The following paragraphs highlight some experiments that are significant for their scope and coverage.

In Chile, the Under-Secretariat for Communications (SUBTEL), through the Telecommunications Development Fund, is implementing the *Todo Chile Comunicado* plan, which originated with the agriculture ministry's Rural ICT Round Table (*Mesa TIC Rural*). It seeks to bring mobile broadband service to 1,474 rural communities and in this way to have 90% of the country's households connected by 2012. The plan, which carries a cost of US$40 million and includes user service subsidies, will benefit 3 million individuals. Localities were selected on the basis of population density as well as their productive potential and agricultural priority. The plan is being promoted through a public-private partnership between ENTEL and FIA (SUBTEL, 2011).

Brazil instituted the National Rural Telecommunications Programme by means of a decree (MC/431-2009), to provide simultaneous telephone and Internet services with a priority focus on rural properties and free service to public schools. The programme is supplemented with the National Broadband Plan designed to offer individual and collective access and 3G networks in 3,000 municipalities by 2014. It includes a subsidy that will bring the cost of Internet service down to R$30 in order to make it accessible to the lowest income population groups (Pinto Martins, 2009). The National Broadband Plan will cost an estimated total of US$7.3 billion and is expected to reach 40 million households, many of them in rural areas. The operation involves the state enterprise Telebras as infrastructure manager and private firms as operators. For the more remote rural areas, the services will be provided through public programmes (Planalto, 2011).

Uruguay has entered a new stage, arranging for the state enterprise ANTEL to offer free Internet to all telephone subscribers and to broaden rural coverage as well. This initiative goes hand-in-hand with the "rural roots" programme (*Plan de Radicación de Poblaciones Rurales*) designed to lay the conditions for people to remain in their place of origin. Rural service was launched in the Department of Artigas, and it was to be expanded to other regions in the course of 2011 (ANTELb, 2011).

In Peru, the Telecommunications Investment Fund (FITEL) called for tenders in 2010 for two regional projects to provide rural connectivity: the Juliaca-Puerto Maldonado project (US$ 8.9 million) to serve 374 rural communities with 86,400 inhabitants, and the Buenos Aires-Canchaque project (US$ 15.9 million) to serve 683 population centers with 317,000 inhabitants. A "broadband project for isolated communities" is currently under evaluation: it will combine public subsidies and private operation similar to the Chilean initiative, and will provide connectivity to 3,852 rural localities with 1.6 million inhabitants (Sotelo, 2011).

There is also a range of specific experiments for providing rural connectivity targeted at isolated, low-income localities depended primarily on subsistence farming. These connectivity experiments generally include educational activities, community empowerment, and local agricultural support. The most widespread experiments involve the installation of local wireless networks, usually managed by the communities themselves in partnership with an executing agency. Successful experiments of this kind can be found in Chile (FIA, 2008c), Ecuador (Chamorro, 2008), Peru (Chamorro, 2008; Bossio, 2005; INICTEL, 2011) and Uruguay (ANTEL, 2011).

The most extensive experience in facilitating ICT access for the rural population has involved the implementation of shared public access facilities in the form of telecentres or infocentres. Over the last 10 years nearly all countries have introduced Internet access centers in small rural communities. The most ambitious experiments have been carried out with public financing, but many have been sponsored by NGOs, foundations and academic centers.

Brazil, Colombia, Chile, Mexico, Panama, Plurinational State of Bolivia and Uruguay all offer examples implemented or backed by government institutions that have achieved broad coverage and have required significant investments. All the cases involve national networks operating in urban and rural sectors and comprising hundreds or in some cases thousands of telecentres (see box V.1).

Box V.1

Notable experiments with shared public access centres in Latin America

Brazil has conducted the most massive experiment in implementing public telecentres. In 2011 there were almost 8 thousand telecentres registered, covering 51.5% of rural and urban municipalities. Of these, 1,363 were established by the Banco do Brazil, 870 by GESAC, and the remainder by other agencies. The states with the greatest proportion of telecentres are Minas Gerais (19.7%), São Paulo (17%) and Bahia (9.8%) (ONI, 2011).

In Colombia, the COMPARTEL programme has instituted 1,669 Community Internet Access Centers, many of them located in rural areas. The centers have been set up in schools, which open their doors to the community for access and digital training. They are now operating in five regions covering 70% of the country's municipalities (COMPARTEL, 2011).

In Chile, the National Network of Infocentres had on average more than 1,000 units during the last decade, but their number has now declined to around 600. The most ambitious experiment is that of BIBLIOREDES, which has set up infocentres in public and municipal libraries, many of them located in rural areas (SUBTEL, 2008).

The "e-Mexico" programme runs more than 7 thousand digital community centers, many of them in small towns, with the greatest concentrations in Oaxaca (706), Sonora (1519) and Puebla (465) (Ferrer, 2009).

In Uruguay, ANTEL has developed a broad network of community access centers. Many of these are MEC centers located in schools and complemented with the Ceibal Plan (ANTEL, 2011b).

Along with the publicly-financed telecentres and infocentres, private entities have joined together to form networks that in some cases constitute true social movements in support of democratizing ICTs; for example, telecentre.org, CDI, etc. (Masio, 2006; Rojas, 2010).

A review of these experiments suggests that public shared access centers have been a qualitatively significant mechanism for digital inclusion associated with dissemination, training, access to information, generation of networks, and community empowerment (Maeso, 2007; Rojas, 2005). Yet, there are limits to their social and financial sustainability, and their continuity typically requires ongoing support from sponsors in both technical and economic terms (Caicedo, 2008; Rojas, 2010). There is evidence that, while telecentres and infocentres are very useful instruments for rural populations, farmers are still reluctant to use them (Nagel, 2005).

Source: Prepared by the author.

Cybercafés offer an alternative for shared access that is of growing importance for rural people and small farmers. While there are no statistics for estimating the total number of cybercafés located in rural areas or small towns, there are signs that it is growing rapidly and that rural people are making heavy use of the service. A study conducted in 2007 estimated that of all the urban and rural shared access centers in the region, 63% were private and the great majority of these were cybercafés (Maeso, 2007). Statistics on rural facilities confirm the growing popularity of this form of shared access.

Programmes to equip rural schools with connectivity and educational hardware and software are also enhancing ICT access for rural inhabitants and small farmers. This is due not only to the demonstration effect, cited earlier, but also to the fact that in many cases the schools are open to the community, offering services similar to those in the telecentres or cybercafés. This approach holds great potential in terms of strengthening communities' social capital and improving producers' access to information.

Table V.2
Examples of community-based access networks

Country	Institution or network
Bolivia (Plurinational State of)	-Red TICBOLIVIA
Brazil	-Information and Business Telecentres Association -GESAC: Federal Government Digital Inclusion Programme
Colombia	-Compartel National Telecentre Network
Chile	-Biblioredes Infocentres -INDAP-CDI Telecentres -REDES Programme
Ecuador	-Ecuador Telecentres Network
Guatemala	-Digital Community Centers
El Salvador	-Connection to Development Telecentres Association
Mexico	-Digital Community Centers
Nicaragua	-Nicaragua Telecentres Network
Panama	-Infoplazas Network
Peru	-Huaral Agriculture Information System Telecentres -Sierra Sur Telecentres Project -Rural Telecentres of Peru
Dominican Republic	-Caribbean Partners Telecentres
Uruguay	-MEC Centers -CASI ANTEL Centers
Venezuela (Bolivarian Republic of)	-Association of Virtual Libraries of Aragua

Source: Prepared by the author

2. Contents and services

Agricultural institutions have typically responded to the ICT challenge by establishing platforms and information systems. For several decades now, with the support of international agencies such as FAO and IICA, public and academic institutions have been developing agricultural information systems associated with libraries, documentation services and statistical units. ICTs have transformed systems by facilitating the assembly, systematization, exchange and flow of information. The result is a significant number of digitally-based agricultural information systems, used essentially by specialists but also open to the general public and to farmers.

ICTs have also facilitated the functioning of international agricultural information networks, monitored by international agencies or member entities (see table V.3). Examples are the Agricultural Information and Documentation Service of the Americas (SIDALC), formed by an agreement between IICA and the Tropical Agriculture Research and Higher Education Centre (CATIE) and the Caribbean Agricultural Information Service established by the Caribbean Agricultural Research and Development Institute (CARDI). Another interesting initiative for generating a comprehensive, user-friendly information platform is the IDI Platform sponsored by FIA in Chile, which allows one-stop access to full information on the Chilean agriculture and forestry sector using common search and management criteria and offering real-time online solutions (FIA, 2011).

What is missing, however, is a bridge between information platforms and small farmers. A number of studies show that farmers are making little or no use of the abundant information available. This is due not only to the constraints and barriers discussed above but also to the characteristics of the systems and portals: they are not user-friendly in their design, they require registration and a password, their information is scattered and complex, and there is a lack of up-to-date information and data of regional or local interest.

There was also a wide range of services available –cellular messaging, early warning, remote diagnosis and geo-referencing– which were of little use by farmes because of their problems in working with ICTs. At least seven countries have developed information systems that are accessible by cell phone, the tool most widely used by farmers. The systems operate by sending messages to cell phones, typically conveying price information and news (see box V.2). This channel should in theory be able to reach significant groups of producers, but in practice its usefulness is limited because farmers are not in the habit of text messaging.

Table V.3

Examples of agricultural information systems in Latin America

Country	Institution	Programme name
Argentina	INTA	RIAN: National agricultural information system
Argentina	Ministry of Agriculture, Livestock and Fisheries	SIIA: Integrated agricultural information system
Brazil	EMBRAPA	-Infoteca-e -Videoteca Digital
Brazil	Agriculture Department of Paraná	Universidade do Campo (&)
Brazil	Government of Minas Gerais	Agridata
Central America	Central American Agriculture Council, now in the process of establishment	Central American agro information system (SICagro)
Colombia	Ministry of Agriculture and Rural Development	AGRONET: Agricultural science and technology information system in Colombia
Colombia	Agriculture and Fisheries Department of Valle del Cauca	Cauca Valley agricultural information system (SISAV)
Costa Rica	Ministry of agriculture and livestock	Costa Rican agricultural information system (INFOAGRO)
Chile	FIA	IDI Platform
Chile	National Irrigation Commission	ESIIR: Integrated system of information on irrigation
Chile	FIA	Agro-forestry information network of Chile (REDAGRO)
Ecuador	Ministry of Agriculture, Livestock, Aquaculture and Fisheries	SIGAGRO: Geographical and agricultural information system
El Salvador	Ministry of Agriculture and Livestock	Agricultural health information system (SISA)
El Salvador	MAG	Fruit market information system
Mexico	SAGARPA	SIAP: agrifood and fisheries information service
Guatemala	Ministry of Agriculture, Livestock and Food	Crop monitoring system
Nicaragua	MAGFOR	MAGFOR agricultural information system
Panama	Agricultural Marketing Institute	Agribusiness information system (SIPAN)
Peru	Ministry of Agriculture	Agricultural information system (SISAGRI)
Dominican Republic	Centre for Agricultural and Forestry Development (CEDAF)	Agricultural and forestry documentation and information network (REDIAF)
Uruguay	MGAP	Agricultural census information system(SICA)

Source: Prepared by the author

Finally, Ministries of Agriculture have been making progress with electronic government as a way of facilitating relations with users. Most ministries and sectoral services have mounted public service and transparency systems at their portals designed especially to receive complaints and suggestions and to provide information on processes. In addition, it is often possible to obtain and download official forms, but facilities for completing transactions electronically are still rare. Once again, there is no clear evidence on the percentage of small farmers who make use of these services. Nevertheless, these instruments represent important options for expanding the use of ICTs, provided they are accompanied by specific provisions for dissemination, training and coaching.

Box V.2
Early warning systems for agriculture via cellular messaging in Latin America

In **Chile**, INTA has established a potato blight control network which, linked to agro-climatic networks, makes it possible to operate a warning and prevention system in a specific geographic area in the south of the country where there are many small farmers (Chacón, 2011).

The NGO CIDMA has developed an agricultural alert system in the Valley of San Lorenzo Tambo Grande in **Peru**, designed not only to respond to emergencies but also to prevent the consequences of climate change. The system is based on the development of local capacities and community participation in its management (Dedios, 2011).

Brazil has established an early warning system concerning soybean rust for the Campos Gerais region of Parana, which combines mapping and weather monitoring in order to locate probable outbreaks of the disease and to support agronomists in their decisions. This is a case of multi-institution collaboration with two universities (Londrinas and Ponta Grossa), an agronomy institute (IAPAR) plus EMBRAPA and ABC Foundation (FORAGRO, 2007).

Except for specific experiments such as these and similar ones elsewhere, where services are provided as part of a broader support effort with a comprehensive focus, such services are still for the most part unavailable and little used by small farmers.

Source: Prepared by the author

3. Digital capacity-building

The third vertex of the ICT development triangle comprises strategies that focus on users and agricultural operations. The low level of schooling and the advanced age of producers are variables about which little can be done in the short and medium term and which must instead be regarded as parameters to be taken into account in policies, working on methodological solutions that can offset or mitigate their effects.

One element that is increasingly seen as an important barrier is that farmers see little need for ICTs. This factor is susceptible to action, provided that ICTs are inserted into management support programmes in ways that will demonstrate their utility.

In this respect, over the last decade several countries have conducted digital literacy campaigns that have included rural areas, either in the context of national digital agendas or sector-specific initiatives. Significant initiatives of this kind have been launched in Chile, Brazil, Plurinational State of Bolivia, Peru, Mexico and Colombia, among other countries. Generall, these campaigns have not been accompanied by any systems of continuity and support for strengthening acquired capacities and putting them into use. Consequently, the effort is very likely to have been diluted in many cases, and to have had much less than the expected impact (Marti, 2008).

At the same time, rural school networks have been used both for disseminating ICTs and for conducting digital literacy activities. Such experiments can be found, for example in Chile, with the *Red Enlaces*, and in Uruguay, with the *Plan Ceibal*. With its connectivity and equipment, the school can serve as a focal point for beaming messages about computer and Internet use to the surrounding community and to parents, many of whom are small farmers (Ekhos, 2003; Plan Ceibal, 2011).

Despite this progress, public agriculture agencies are still sponsoring few systematic and sustained programmes of digital education for small farmers. Generally speaking, agriculture agencies seem to leave the responsibility for digital literacy to Ministries of Communications or to government agencies responsible for digital policy. Thus, there are few large-scale experiments sponsored by agriculture ministries or their associated agencies. The Agricultural Development Institute of Chile constitutes an exception to this rule, as it has in past years included digital literacy campaigns implemented by consulting firms as part of its technology development and transfer activities (INDAP, 2007). There are also some significant experiments in the region for developing digital capacities among groups of small farmers participating in broader projects of digital inclusion sponsored by national and international private entities (see box V.3).

Box V.3
Digital capacity development projects for small farmers in Latin America

The Rural Information System of Arequipa (SIRA) in Peru, implemented with support from GTZ-GATE and executed by the Agricultural Society of Arequipa, showed that it was possible to introduce ICT use even among older farmers with very little education. The training was associated with the delivery of information for which farmers felt great need and incentives for the beneficiaries themselves to participate in managing the system (Bossio, 2005).

The *Red TICBolivia* network, sponsored by the International Institute for Communication and Development (IICD), is a special experiment that brings together public and private agencies, community organizations, foundations and NGOs and covers a broad range of digital inclusion projects, notably the establishment of telecentres. Most of the experiments are located in rural areas or small villages, and digital literacy has been a key tool for achieving digital inclusion. Assessments show a high degree of ICT adoption among small farmers participating in the experiment (Red TICBOLIVIA, 2010).

In Uruguay, the Instituto Plan Agropecuario (IPA), with the support of Chile's CENDEC, conducted an experiment for incorporating ICTs into the management of livestock operations: it included training, software development and technical assistance. It was targeted at small and medium-scale livestock breeders in the eastern region of Uruguay, and served to strengthen digital capacities and increase farmers' adoption of ICTs. A similar experiment was carried out in Panama with members of cooperatives belonging to the Association of Small and Medium-Sized Producers of Panama (APRMEP).

Source: Prepared by the author.

4. Integrating ICTs into firms and production chains

Several countries in the region have experimented with ways to introduce ICTs in small business management, in the context of value chains (see box V.4). These experiments have been conducted for the most part by nongovernmental organizations.

The competitiveness demands of international markets have led countries to set quality standards and impose traceability requirements for agricultural products, and these have been expressed in specific standards that businesses must observe (see table V.4). Those standards have brought about changes in management and production processes and have provided an incentive for the introduction of ICTs in agricultural businesses, in government institutions responsible for agricultural regulation and supervision, and among firms and professionals providing advice and support for these processes. The greatest progress has been made in the livestock sector (see box V.5), where seven countries, responding to regulatory demands in Europe and North America, have introduced animal traceability systems based on computer technologies that include complex platforms, operating instruments and specific applications (Schneider, 2010; ECLAC, 2010a).

Box V.4

Programmes for incorporating ICTs into small agricultural operations in the context of value chains

In Cusco, Peru, in the district of San Salvador, the Puno-Cusco Corridor Project and PROCASUR supported establishment of the Business Information Centre for the network of kiwicha (amaranth) producers with a view to improving business transactions through Internet use. A similar experiment in the Plurinational State of Bolivia, also supported by PROCASUR, involves the federation of coffee producer cooperatives (GENCOOP) in Coroico, province of Nor Yungas, where a telecentre is used for exchanging information on coffee quality and export support (PROCASUR, 2011).

The Association of Ecological Producers of Bolivia (AOPEB) has established technical and commercial information centers for growers of organic cocoa, coffee and tropical fruits. They are providing support for business decision making to 51 member associations, covering 30,000 farmers (AOPEB 2011; IICD 2006).

There are several experiments of this kind in Chile. The most important are those sponsored by FIA as part of its mission to encourage agricultural innovation. One involves the establishment of the *YoAgricultor* platform, integrating information systems, management instruments, and development of a virtual community. Another, conducted jointly with CODESSER, seeks to generate a comprehensive system that includes info-communication, hardware and software, training and development of a management system for fruit producers in San Felipe and Los Andes (FIA, 2008).

Also in Chile, INDAP introduced a programme to equip business cooperatives and provide digital training to encourage the introduction of ICTs in farming activities. As well, the Universidad Austral has implemented the INNOVA CORFO project to introduce ICTs on 300 small farms, developing a platform and an online advisory system together with training (UACH, 2010).

In Uruguay, IICA is implementing the SENDA plan for democratizing information in the model market of Montevideo, which seeks to create a virtual community of 500 SMEs for information on agricultural products supply and demand, training and technical assistance (De Sosa, 2011).

Source: Prepared by the author

Table V.4
Countries with livestock traceability systems

Country	Name of System
Argentina	National system of beef cattle for export (SIGBE) Integrated animal health management system (SIGSA)
Brazil	Buffalo and beef origin identification system (SISBOV)
Colombia	National beef cattle identification and information system (SINIGAN)
Chile	Official sanitary traceability programme
Mexico	National system of individual cattle identification (SINIIGA)
Paraguay	Paraguay traceability system (SITRAP)
Uruguay	National cattle information system (SNIG) Animal registration and information system (SIRA) Electronic meat industry information system (SEIIC)

Source: Prepared by the author
Note: Nicaragua is in the initial stage of implementing the system

Box V.5
Animal and fruit traceability systems in Latin America

Livestock traceability systems in the region are at various stages of development, and some are still in the experimental phase or are of partial application and voluntary membership. Uruguay has the most advanced cattle traceability system, one that has served as a model for the region: it involves the use of electronic readers, data transmission via wireless Internet, and a GIS system (SNIG, INAC, 2011).

Several countries have also introduced fruit and wine traceability systems, with Argentina, Chile and Uruguay in the lead. In Chile, the Fruit Development Foundation (FDF) has developed a fruit traceability system described in a digitalized manual. ERP systems are also being introduced in the wine industry to oversee traceability at all stages of the chain; the system has been replicated in the province of San Juan in Argentina (Ares, 2011). In Uruguay, the MGAP recently installed a system for phytosanitary certification of citrus fruit for export, which allows for traceability of export lots all along the production-export chain (Tecnolimpia, 2011; SONDA, 2011).

Nevertheless, it seems that small farmers have very little involvement in these experiments with animal and fruit traceability, because of the inherent demands in terms of capitalization, technology and scale.

Source: Prepared by the author

The situation with respect to the development of software and applications for agriculture is determined both by abundance and scarcity. A software market survey (which did not include Brazil) conducted for this study revealed 80 systems that had been developed or adopted by firms in the region. In the case of Brazil, EMBRAPA has identified 405 software programmes available in the areas of administration and management, rural process control, animal production and agricultural crops (Mendes, 2009). EMBRAPA itself has available 68 software programmes developed by 19 of its units, covering most of the phases and operations of an agricultural firm (EMBRAPA, 2011a). There are various ERP systems available for agricultural chains and agro-industry firms for comprehensive product management and traceability. On the other hand, there is little or no simple software suitable for use on small farms (CENDEC, 2011).

Precision agriculture is perhaps the area with the greatest potential for ICT application in agriculture, yet it is still underdeveloped in countries of the region. Although its potential has been demonstrated, most farmers, especially small ones, are strangers to it. The countries with the greatest degree of development and with significant areas under cultivation with PA are Argentina and Brazil. Colombia, Cuba, Chile and Uruguay are now conducting more limited experiments, in some cases still in the early stages, led by the INIAs or universities. Yet small farmers in Latin America face great barriers to participation in experiments of this kind, because of lack of capital, productive skills, management systems and the characteristics of the producers themselves.

Lastly, with the exception of a few experiments cited above, no effort is being made to incorporate ICTs into the extension services and technical assistance provided by public institutions. This is a serious failure, given the demonstration effect that such activities can have on farmers. The INIAs and universities have sponsored experiments, some of them cited above (and elsewhere in this book), which are beginning to use ICTs in technical assistance, but for the most part such assistance continues to be provided in the conventional in-person manner.

I. Conclusions and recommendations

Moving to a knowledge-based agriculture is a challenge and an obligation for countries of the region. ICTs can contribute greatly to agricultural development and they are applicable in nearly all phases and areas of agricultural activity. It must be recalled, however, that the adoption of

ICTs by agricultural enterprises is a complex process that involves various stages and is conditioned by the structural heterogeneity and stratification of farmers. An even greater challenge is to make active use of ICTs in knowledge management within value chains.

There are global tendencies in the region that are exerting pressure for the adoption of ICTs in agriculture. The most important are market competitiveness demands, the growing availability of electronic operations by institutions, social and communicational pressures generated within farmers' own families, the growing ICT component of technology, and digital promotion activities.

At the present time, however, in most countries farmers have the least access to ICTs among all occupational categories of the rural population. Access to ICTs in rural households is generally very low, and there is a sharp discrepancy between the widespread use of cell phones and the scant utilization of computers and the Internet. There are also differences between farmers residing in urban areas and those living in the countryside, who have lower levels of ICT access.

Education seems to be an important constraint for accessing ICTs in the case of small farmers, but connectivity remains a central barrier: availability is scarce, prices are high and in many cases the quality is low. The fact that the production chains and markets in which most farmers still operate are not very demanding in terms of information and knowledge is another factor that limits the adoption of ICTs.

When it comes to policies, most countries have formulated digital agendas to promote access to the information society. To varying degrees, those policies reveal a concern for digital inclusion for rural sectors, with particular attention to infrastructure and connectivity issues. Yet, they do not contain strategies designed to bring farmers into the digital world. Nor, with a few exceptions, are there any specific digital strategies for agriculture at the sector level.

As to recommendations for addressing the barriers identified, experience shows that strategies must include coordinated actions to change various factors that influence the adoption of ICTs. Isolated initiatives relating to connectivity, training or information are not enough: it is the complementarity of factors that will produce lasting results.

Experience to date suggests that strategies must address the twin concerns of inclusion and competitiveness in light of the heterogeneity of farmers, their differing levels of access to ICTs, and the pronounced digital divide within the sector. The challenge is to include marginalized producers but at the same time to create conditions for the full use of digital resources by the region's leading-edge agriculture firms. Heterogeneity also means that policies must be differentiated in light of technological levels, production scales, and the characteristics of the agricultural chains.

Assuming that there will be accelerated growth of ICTs in society and that national telecommunications agencies will take the lead in providing connectivity and ensuring its coverage and quality, sector-specific efforts should focus primarily on having farmers adopt ICTs in their management practices and in the productive technologies they use. This presupposes a series of measures relating to the enterprise, its environment, agricultural research, extension services, and productive development.

Experience in the region and the technological advances of recent years suggest that the provision of connectivity for rural areas should soon cease to be an insurmountable barrier. Solutions will require supply-side subsidies to reduce prices and make them affordable to the bulk of the rural population and in this way guarantee sustainability.

Until there is generalized individual access to the Internet it will be important to ensure the sustainability of shared access centers and to introduce them in agricultural development initiatives. This will mean addressing the financial sustainability problems of the telecentres through strategies that combine subsidies with self-financing achieved by providing other, complementary services. Shared access centers should also be part of broader strategies for digital and civics training, community services and the use of information in agricultural chains.

Digital literacy must remain a priority, but in the context of broader programmes of technological innovation and agricultural development. Agriculture ministries should support digital literacy programmes for farmers in coordination with extension services and activities related to productive development and technological innovation. Digital literacy campaigns and hardware subsidies will be ineffective unless they are accompanied by actions to consolidate the use and adoption of ICTs in productive activity and in producers' daily communications. These actions should also be combined with efforts to publicize and promote the use of the electronic services offered by public institutions.

Experiments for providing connectivity and equipping rural schools with IT facilities have shown their ability to bring rural communities closer to the information society both through the incentives they produce in families and through the digital services they make available to the community. With a few exceptions, however, there has to date been little integration between the efforts of Ministries of Agriculture and these IT programmes for rural schools. The spread of telemedicine services can also help to motivate rural residents to join the world of ICTs.

The real challenge today is not so much to add information to the web but to make it accessible and manageable for farmers. Focused, accurate and up-to-date information with the greatest possible local interest should be a goal for institutional portals and information systems targeted at producers. Another important goal of e-government should be to digitalize to the maximum those procedures, formalities and transactions that involve farmers. The establishment of "single windows" and portal interoperability can facilitate transactions, speed procedures, and encourage institutional exchange.

Because producers have little understanding of digital facilities and their benefits, special campaigns are needed, using the traditional media (radio, television, print and visits), to encourage their use. Demonstration projects included in extension programmes or in the training offered at telecentres can do much to expand the use of virtual facilities. Systems should also be introduced to transmit information to farmers using the most widespread platforms, such as cell phones. The content of the message needs to be selected carefully with a view to demonstrating its effective, real and immediate usefulness.

ICTs should be introduced progressively into technical support and productive development programmes for farmers. This means moving from relatively simple actions to the complete transformation of extension and innovation methodologies. An initial approach is to equip institutional portals with facilities for electronic consultation with experts. More sophisticated modalities include remote diagnosis of pests and diseases and remote phytosanitary assistance.

The allocation of special funds to promote the generation or adaptation of precision agriculture systems should be a priority in those countries where the agrifood chains are suitable for such technologies. Also, steps should be taken to produce, validate, adapt and introduce comprehensive management systems that will guarantee information and supervision throughout the agrifood chain. The progress that some countries in the region have made in these areas suggests the feasibility of collaboration and support for transferring technologies to countries that want to conduct similar experiments.

Experience shows that cooperatives and similar arrangements can be a powerful platform for generalizing the information society in rural areas. The majority of successful experiments are based on some kind of strong community association, and ICTs can in fact contribute to strengthening cooperative ties and boosting community social capital. ICTs should also be an instrument for empowering farmers both in productive and technological terms and in terms of their role as citizens. To this end, strategies should include mechanisms to strengthen producers' participation in formulating digital policies and taking decisions about them.

Despite the great number and diversity of ICT experiments in the region, there have been very few evaluations for drawing lessons and transferring knowledge and technologies within the region. It is important, then, to encourage the evaluation of those experiments with the greatest potential for replication, such as cellular messaging, remote diagnosis, virtual communities, and online technical assistance.

Given the need for comprehensive and articulated strategies for promoting ICTs, institutional coordination bodies are needed to define joint strategies, to articulate actions, and to foster institutional synergies. Lastly, recognizing that some countries are more advanced than others and have developed relevant expertise in promoting ICTs for agriculture, mechanisms should be established to promote exchanges and transfers of experience among countries. This could be accomplished through workshops, visits and technological support activities in ICTs and agriculture.

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Acronyms

ANTEL:	Empresa de Telecomunicaciones del Uruguay
BID:	Banco Interamericano de Desarrollo
CARDI:	Caribbean Agricultural Research and Development Institute
CASI:	Centros de Acceso a la Sociedad de la Información (Uruguay)
CATIE:	Centro Agronómico Tropical de Investigación y Enseñanza
CDI:	Comité para la Democratización de la Informática
CEDAF:	Centro para el Desarrollo Agropecuario y Forestal (República Dominicana)
CEDE:	Centro de estudios sobre Desarrollo Económico U. de Los Andes (Colombia)

CEED:	Centros de Estudios de la Economía Digital
CENDEC:	Centro para el Desarrollo de Capital Humano (Chile)
CEPAL:	Comisión Económica para América Latina y El Caribe
CIDMA:	Centro para la Investigación, Desarrollo y Defensa del medio Ambiente (Perú)
CODESSER:	Corporación de Desarrollo Social del Sector Rural (Chile)
COMPARTEL:	Programa de Telecomunicaciones Sociales (Colombia)
CORPOICA:	Corporación Colombiana de Investigación Agropecuaria
EMBRAPA:	Empresa Brasileira de Pesquisa Agropecuaria
ENTEL:	Empresa de Telecomunicaciones (Chile)
ERP:	Enterprises Resource Planning. Sistemas de gestión integral para empresas.
FAO:	Organización de las Naciones Unidas para la Agricultura y la Alimentación.
FDF:	Fundación para el Desarrollo Frutícola (Chile)
FIA:	Fundación para la Innovación Agraria (Chile)
FIAGRO:	Fundación para la Innovación Tecnológica Agropecuaria (El Salvador)
FITEL:	Fondo de Inversión en Telecomunicaciones (Perú)
FODEPAL:	Proyecto Global de Cooperación Técnica para la Formación en Economía y Políticas Agrarias y Desarrollo Rural
FORAGRO:	Foro de las Américas para la Investigación y Desarrollo Tecnológico Agropecuario
IICA:	Instituto Interamericano de Cooperación para la Agricultura
ICEX:	Instituto Español de Comercio Exterior
INCARURAL:	Instituto Nacional para el Desarrollo de Capacidades del Sector Rural (México)
INIA:	Instituto de Investigaciones Agropecuarias (Chile) Instituto Nacional de Innovación Agraria (Perú) Instituto Nacional de Investigación Agropecuaria (Uruguay)
INICTEL-UNI:	Instituto Nacional de Investigación y Capacitación de Telecomunicaciones (Perú)
INIFAP:	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (México)
INDAP:	Instituto de Desarrollo Agropecuario (Chile)
INTA:	Instituto Nacional de Tecnología Agropecuaria (Argentina)
IPA:	Instituto Plan Agropecuario (Uruguay)
ITU:	United Nations Agency for Information and Communication Technologies

LATU: Laboratorio Tecnológico del Uruguay
MAG: Ministerio de Agricultura y Ganadería (El Salvador)
Ministerio de Agricultura y ganadería (Paraguay)
MAGFOR: Ministerio Agropecuario y Forestal (Nicaragua)
MDRyT: Ministerio de Desarrollo Rural y Tierras (Bolivia)
MEC: Ministerio de Educación y Cultura (Uruguay)
MGAP: Ministerio de Ganadería, Agricultura y Pesca (Uruguay)
MINAG: Ministerio de Agricultura (Perú)
MINAGRI: Ministerio de Agricultura, Ganadería y Pesca (Argentina)
Ministerio de Agricultura (Chile)
OCDE: Organización para la Cooperación y el Desarrollo Económico
ODEPA: Oficina de Políticas Agrarias (Chile)
ONGS: Organizaciones no Gubernamentales
PIMA: Programa Integral de Mercadeo Agropecuario (Costa Rica)
PROCADIS: Programa de Capacitación a Distancia INTA (Argentina)
PROCASUR: Programa regional de Capacitación en Desarrollo Rural
PROCIANDINO: Programa Cooperativo de Investigación y trasferencia de Tecnología Agropecuaria para la Subregión Andina
PROCISUR: Programa Cooperativo para el Desarrollo Tecnológico Agroalimentario y Agroindustrial del Cono Sur.
PROTIC: Inventario Regional de Proyectos en Tecnologías de Información y Comunicación para América Latina y El Caribe
SAGARPA: Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (México)
SENA: Servicio Nacional de Aprendizaje (Colombia)
SDD: Secretaría de Desarrollo Digital (Chile)
SIAP: Servicio de Información Agroalimentaria y Pesquera (México)
SIDALC: Servicio de Información y Documentación Agropecuaria de las Américas.
SUBTEL: Subsecretaría de Telecomunicaciones (Chile)
UAH: Universidad Alberto Hurtado
UFSM: Universidad federal de Santa María (Brasil)
UNI: Universidad Nacional de Ingeniería (Perú)

VI. ICTs in public agricultural institutions in Latin America: Uruguay, Costa Rica and Paraguay case studies

Hugo Chavarría

A. Introduction

Information and communication technologies (ICTs) are not objectives in themselves. On the contrary, they are instruments that facilitate the construction of knowledge, communication, exchange and decision-making. As noted in the 2009-2014 National Telecommunications Development Plan of Costa Rica, ICTs by themselves cannot resolve a country's political, economic and social problems, but they can be used to expand opportunities for the various sectors of society to reap their benefits.

Incorporating ICTs into the work of public agriculture institutions can not only enhance the profitability and productivity of their economic and human resources, but can also enlist new players in technical assistance, expand geographic coverage, and offer products and services better suited to the needs of their client. However, because the incorporation of ICTs in public agricultural institutions of Latin America and the Caribbean (LAC) is relatively recent, there are few available examples of positive, concrete and measurable results. Moreover, due to the shortness of the initiatives carried out in the region, there has not been sufficient time and results to identify the factors that are limiting the impact of ICTs in public agriculture institutions.

To generate inputs for ICT initiatives in public agricultural institutions and to retrieve the lessons learned from experience in countries that are in the vanguard in this area in LAC, the IICA Centre for Strategic Analysis for Agriculture (CAESPA) undertook a study to identify and analyze the main factors delaying or limiting the impact of ICTs in those institutions. This paper summarizes the main findings and conclusions from that process, which involved not only a thorough bibliographic and methodological review, but also a series of workshops for characterizing ICTs in public agricultural institutions in Uruguay, Costa Rica and Paraguay.

B. Methodology

The great majority of instruments designed for measuring the degree of access to ICTs and their use are based on surveys or on rigid frameworks that suffer several drawbacks: (a) they are difficult to adapt for measuring the degree of access to ICTs and their use in the agriculture sector; (b) they focus primarily on the existence of software and hardware, without measuring their use in the provision of technical assistance and extension services; and (c) generally speaking, it is the IT department heads who respond to the surveys, and they may not have much knowledge of the impact of ICTs on final users.

Given these constraints, the Inter-American Institute for Cooperation on Agriculture (IICA) decided to construct a methodology of its own that would make it possible not only to characterize access to ICTs and their use and impact in public agricultural institutions, but also to build a common vision and a national strategy around the issue. This task was facilitated by the work that IICA had done previously on the use of ICT tools in knowledge management for innovation and technical data management and the development of pilot experiments that would be of primary benefit to farmers through the use of ICT tools.

In constructing this methodology, IICA began by identifying the principal components that condition ICT outcomes in public agriculture institutions: on one hand, the national regulatory and institutional framework for ICTs, and on the other hand, access to ICTs and their use and impact in public agricultural institutions. Table VI.1 shows some of the critical variables considered in determining the degree of development of institutions under each component.

Table VI.1
Critical components and variables that condition the impact of ICTs in public agriculture institutions

Components	Variables
Standards	Public policies for ICT Regulatory framework Digital government Electronic signature
Access	Connectivity and Internet Hardware Software Intranet Web
Use	Internal management Service to users Institutional knowledge management Decision-making Human capital development
Impact	Current status: area, productivity and number of products Conditioning factors: Capacities for use, adaptability of tools and exploitation strategies

Source: IICA, instrument for characterizing accessibility, use and factors conditioning the impact of ICTs in public agriculture institutions

In contrast to the tools normally used to measure ICTs, which rely on limited-choice questionnaires or surveys based on Likert-type scales administered to a single thematic expert, the IICA methodology has the advantage of being applied through participatory workshops to various stakeholders representative of public agricultural institutions. These range from institutions responsible for ICT policy at the national level (telecommunications agency, electronic government, ICT Master Plan, digital agenda etc.) to technicians and users in ministries of agriculture, livestock, forestry and fisheries, agricultural research institutes, plant and animal health services, rural development institutes, extension services, etc. This broad representation enhances confidence in the validity of the results.

The focus groups discussed the scenarios posed for each of the critical variables and individually selected the one that best reflected their circumstances. For each of the variables, the methodology presents a clear and concise definition, and spells out all the feasible scenarios. In this way, the methodology has a kind of "thermometer scale", where the first option corresponds to the least-development scenario and the last option to the greatest-development scenario (table VI.2 presents as an example the scenarios discussed in the case of the national normative framework for ICTs).

Table VI.2
Presentation of each variable in the characterization methodology
Normative framework for ICTs

This comprises the set of concrete decisions that give rise to public policies that are expressed in national constitutions, international agreements, codes, laws, regulations and decrees.
Characterization
There is no normative framework to regulate and promote ICT access and use.
There is a normative framework to regulate and promote ICT access and use, but compliance is voluntary.
There is a normative framework to regulate and promote ICT access and use, which is of mandatory observance at the national level and is expressed in regulations and decrees.
There is a normative framework to regulate and promote ICT access and use, which is of mandatory observance at the national level and is expressed in concrete laws or codes.
There is a normative framework to regulate and promote ICT access and use, which is of mandatory observance internationally and is expressed in international agreements signed by the country and in force.

Source: IICA, instrument for characterizing accessibility, use and factors conditioning the impact of ICTs in public agriculture institutions

C. Principal results

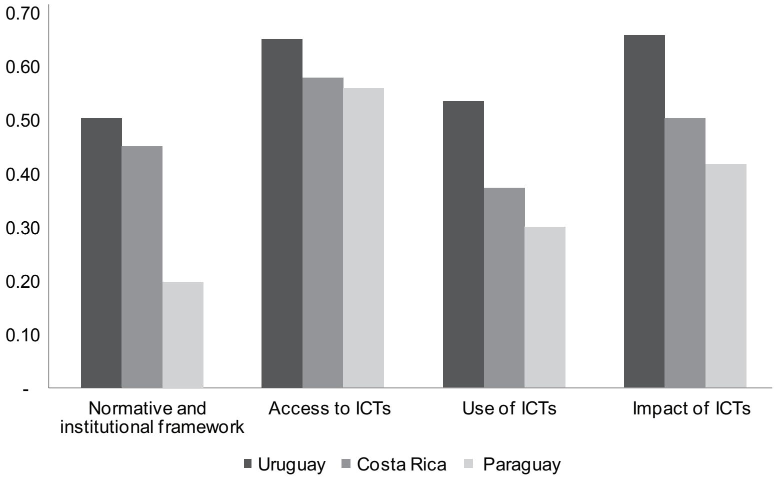
1. National normative and institutional framework

Of the three countries examined, Uruguay appears clearly as having the highest degree of development in access to ICTs and their use and impact in public agriculture institutions (see figure VI.1). Not only has Uruguay been pursuing a digital agenda for the last four years, but it also has executing units and financial resources for implementing its projects. In contrast to many countries where legislation carries with it no enforcement or budget provisions, Uruguay has made significant progress in implementing concrete projects for incorporating ICTs into public institutions. Examples of such projects include the government procurement agency, the electronic file tracking system, *Uruguay concursa*, national public software, citizen funds, one-stop electronic windows, the Uruguay State portal, and e-health.

Costa Rica still has a long way to go, although it has taken some steps to consolidate its 2009-2014 National Telecommunications Development

Plan, primarily by seeking technical and financial resources to implement the Digital Agenda and the Master Plan for Digital Government. At the regulatory level it has approved legislation governing certificates, digital signatures and electronic documents, but in fact the efforts to include ICTs have focused on only a few fields, which do not include public agricultural institutions.

Figure VI.1
Perception of progress with fundamental components



Source: Prepared by the author from the results of the characterization workshops

In Paraguay, the ICT Master Plan was presented less than a year ago and the process of socialization and feedback is just beginning. Moreover, vigorous efforts are being made to set up an executive secretariat for the Master Plan and the Digital Agenda and to make it operational. Although it is still at the initial stages, Paraguay is moving resolutely to establish a modern, responsive and efficient regulatory framework. While it faces constraints in terms of telecommunications infrastructure, Paraguay is moving quickly to construct and implement a regulatory framework for ICTs that will not only meet its needs but will also capitalize on the efforts that public institutions have already made. In this effort it has the support of the Korean government, which has financed a portion of the activities and has publicized successful experiments and lessons learned from other countries and regions.

Box VI.1

The use of ICTs for public procurement in Costa Rica

To improve transparency and economize in its procurement processes, as well as to allow more suppliers to participate, the Costa Rican government adopted an online procurement system at the beginning of 2009, known as Compr@Red.

Between April 2009 and December 2011, Compr@Red allowed creation of more than 2,000 purchase orders, including office and stationery supplies, cleaning services, vehicle spare parts, and travel agencies.

According to data from the Costa Rican Ministry of Finance, Compr@Red has produced savings of more than $6 million during this time thanks to the establishment of five framework contracts with 76 government institutions that are using the system.

According to studies by the Inter-American Network of Government Procurement, the OAS and the IDB, Compr@Red ranks second in terms of maturity among all government procurement systems of LAC.

Source: Ministry of Finance of Costa Rica

Despite these successes, the ICT regulatory framework is generally perceived as one of the components where the least progress has been made, even in the relatively more advanced countries such as Uruguay (see figures VI.2 to VI.4). Yet the fact that workshop participants deemed progress with the ICT regulatory framework to be slow, this does not mean that governments are shirking efforts in this field. As with many other regulatory issues, the perception that progress is slow may be due to stakeholders' lack of knowledge or understanding.

In fact, although the three countries (especially Uruguay) have strategies, legal frameworks, technical standards and institutions responsible for financing and monitoring ICT projects in government institutions, many officials consulted were unaware of them. While it might be expected that private stakeholders would not have detailed familiarity with the scope of the ICT regulatory and institutional framework governing public institutions, it is difficult to explain how officials of public agricultural institutions can be ignorant of these issues.

Box VI.2
Fostering political and technical support for the ICT master-plan in Paraguay

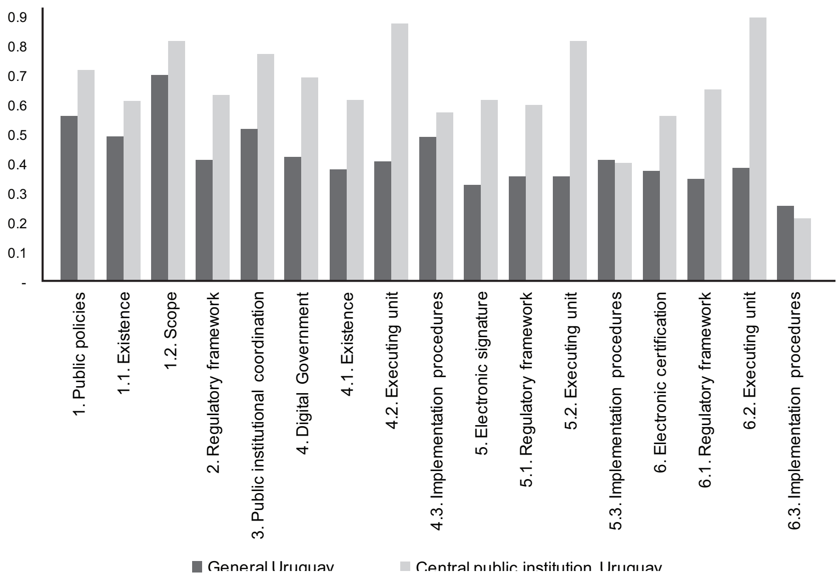
The Paraguayan authorities have recognized clearly that results will not be achieved unless efforts to construct the ICT regulatory framework enjoy support at the highest political levels as well as among technical staff of public institutions.

With this objective, the President's Office (through the Secretary-General) has taken a proprietary interest in the ICT Master Plan from the outset, thereby ensuring that ICT issues would be discussed at meetings of ministers and also facilitating the adoption of decisions.

At the same time, recognizing that it was essential not only to have support at the top but also to sensitize the technicians who would have to implement the actions, the ICT Master Plan concerned itself from the outset with integrating the technical staff of all government institutions. Through technical discussions, social networks and the "balanced scorecard" approach, a participatory planning process was implemented, and it now enjoys political support and technical consent from all its members. Moreover, this work has been supplemented with lessons learned and the forging of links with other countries in the region that have more experience in this field, such as Brazil, Colombia, Uruguay and Chile

Source: Plan Director TIC Paraguay

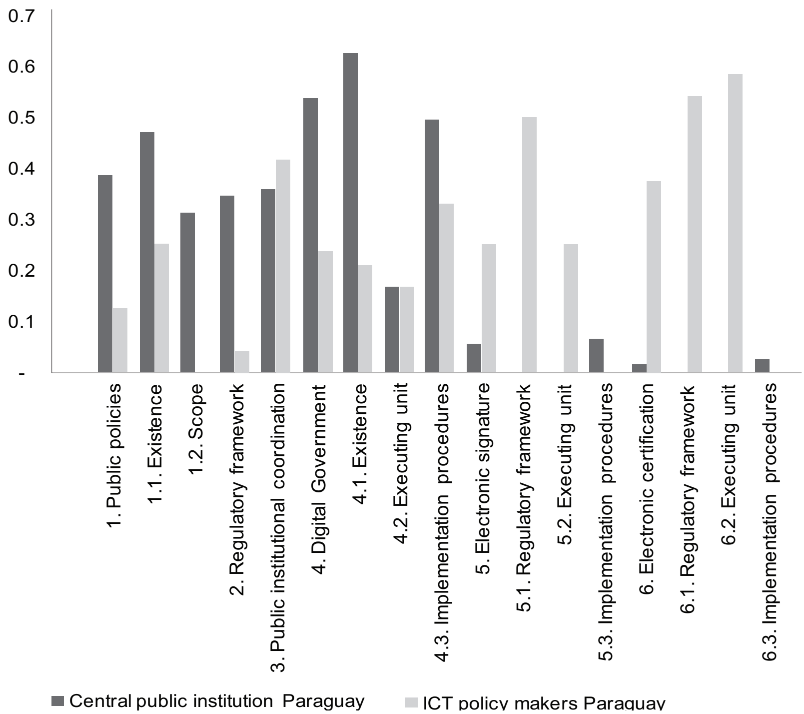
Figure VI.2
Uruguay: perception of the ICT regulatory and institutional framework



Source: Prepared by the author from the results of the characterization workshops

Participants' responses at the characterization workshops, and their comments in particular, revealed that a great many of those from government agricultural institutions (centralized or not) were unfamiliar with the rules and standards that the ICT regulatory framework (electronic government, Master Plan, digital agenda etc.) establishes for their institution's work. The reason for this unfamiliarity is primarily the fact that public agricultural institutions are not a priority for implementing e-government or digital agenda strategies. In the three countries the strategies give priority to the fields of health, education, justice and subnational or municipal administration. The focus on those institutions has meant that there is little communication between the institutions responsible for ICTs and the managers of agricultural institutions.

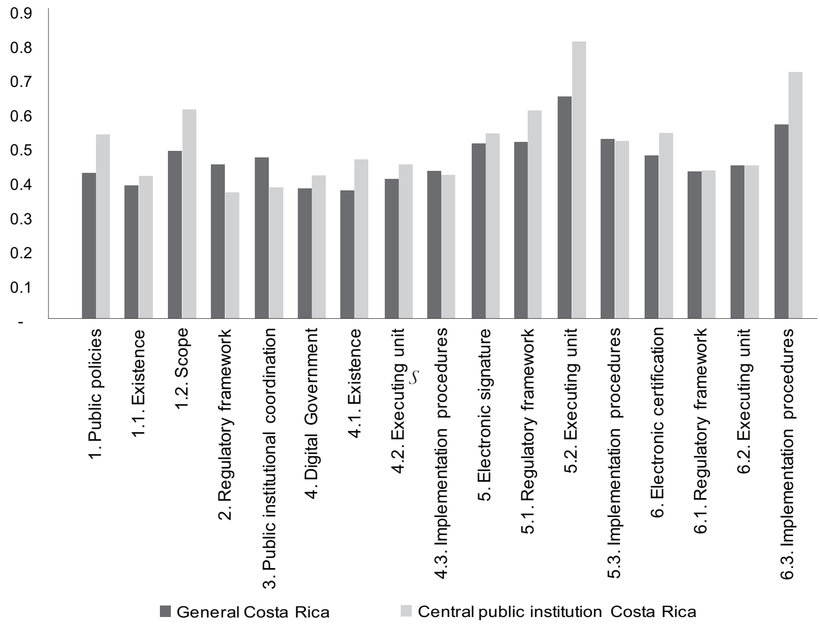
Figure VI.3
Paraguay: perception of the ICT regulatory and institutional framework



Source: Prepared by the author from the results of the characterization workshops

Figure VI.4

COSTA RICA: perception of the ICT regulatory and institutional framework



Source: Prepared by the author from the results of the characterization workshops

As there are no mandatory ICT standards and rules, many of the efforts that public agricultural institutions have been making to implement ICT in their processes are not only incompatible with the national strategy but are also producing overlap and lowering the return on the funds invested.

As was to be expected, the perception of the ICT regulatory and legal framework among workers in the central public agricultural institution (Ministry of Agriculture, MoA) becomes more positive as the framework matures (as measured by number of years since implementation). In fact, in Uruguay and Costa Rica, which were earlier than Paraguay in implementing their ICT regulatory framework, the perception of progress with the ICT regulatory and legal framework is much greater among officials of the Ministry of Agriculture than among any other focus group participating in the workshop.

In Paraguay, by contrast, where the ICT Master Plan is a relatively recent initiative, there is a glaring lack of knowledge about existing ICT legislation in virtually all sectors, including public officials of the MoA. In fact, Paraguay's master plan is so new that serious confusion and information gaps persist: while in some cases progress is overestimated, in other cases it goes completely unrecognized.

Participants from the group of officials of MoA of Paraguay, for example, tended to overestimate the status of public policies, the ICT regulatory framework and digital government, while they were unaware of progress with electronic signatures and certification. This situation is due to the fact that in the early stages of the digital agenda the authorities did not undertake information or socialization campaigns in public agricultural institutions because, as explained earlier, these were not their main target.

Although the countries that have made more progress with their regulatory and legal framework for ICTs have greater knowledge about existing initiatives and their scope, there are still information gaps and shortages of technical and economic resources. For example, since 2008 Uruguay has had a digital agenda with the goal of moving toward the information society by identifying, prioritizing and monitoring strategic programmes and projects. Many institutions participated in its construction and execution, including AGESIC (Agency for Electronic Government and the Information Society) as well as several ministries and other public agencies (Industry, Energy and Mining, Economy and Finance, Education and Culture, Office of Planning and Budget, URSEC, etc.), universities (de la República, Católica del Uruguay, de Montevideo, de la Empresa and the ORT) and civil society organizations.

In 2009 a draft law was approved recognizing the legal validity and effect of electronic documents and electronic signatures. That law guaranteed that a digital signature has the same validity as a certified conventional signature on a public or private document, and that electronic documents have the same legal value and effect as written arguments. More than three years have elapsed since construction of the digital agenda and more than two years since implementation of the electronic signature law, but there is still little knowledge about this regulatory framework among people in the agriculture sector.

With respect to the framework for regulating and promoting access to ICTs and their use, workshop participants generally considered that compliance was voluntary, even when spelled out in regulations, decrees and laws. They also recognized that: (a) implementing the digital government strategy has been impeded by the lack of technical and economic resources; (b) the executing unit does not have the required hierarchy or resources; and (c) that implementation procedures —while defined— are not included in the official government management procedures. The same views were expressed with respect to electronic signature and certification.

2. Access to ICTs in public agricultural institutions

In general terms, access to ICTs in public agricultural institutions will be greater or lesser depending on the penetration of telecommunications in the national territory. Access to cell phones, television and radio as well as the availability and speed of Internet connections determine the availability of these technologies in public institutions.

According to data from the International Telecommunications Union (see table VI.3) there is a wide gap in access to fixed telephone lines, computers and the Internet in the countries studied. While in Uruguay and Costa Rica around 3% of the population has a fixed telephone line and 25% use the Internet, the figures in Paraguay are 10 times lower (0.04% and 2.5% respectively). Moreover, only 6% of people in Paraguay have personal computers.

Table VI.3
ICT access indicators in Uruguay, Costa Rica and Paraguay

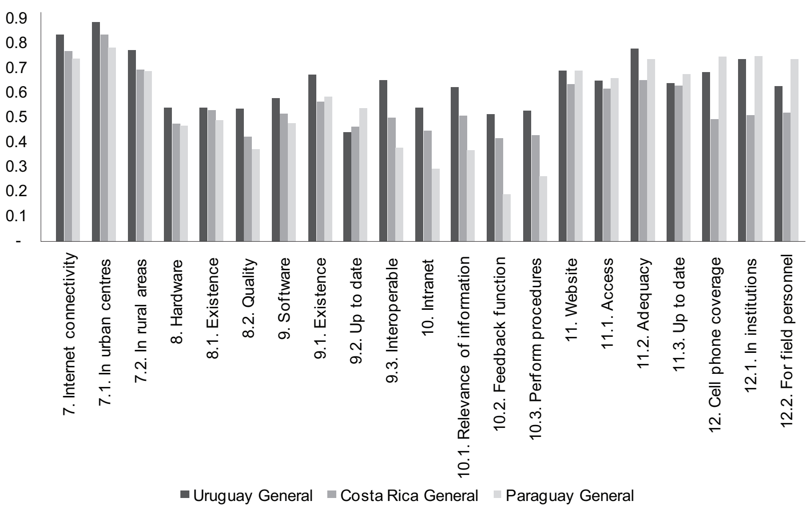
	Uruguay	Costa Rica	Paraguay
Population (millions)	3 455.00	4 322.00	6 216.00
GNP per capita	3 461.00	4 193.00	1 018.00
Human development Index	0.84	0.84	0.76
Literacy rate	98.00	96.00	93.00
Literacy rate (males)	97.00	95.00	94.00
Literacy rate (females)	98.00	96.00	92.00
TV sets per 1,000 persons	530.00	231.00	218.00
Radios per 1,000 persons	603.00	816.00	182.00
Fixed telephone lines per 1,000 persons	30.85	31.62	4.73
Cell phones per 1,000 persons	18.51	21.73	29.38
Personal computers per 1,000 persons	13.27	23.87	5.92
Internet users (thousands)	680.00	1.000.00	150.00
Internet users per 100 persons	20.98	23.54	2.49

Source: Prepared by the author on the basis of the ITU data

Although the indicators for ICT access are not encouraging, it is interesting that most officials and clients of public agricultural institutions do not see this as the main variable limiting the impact of ICTs in those institutions. As can be seen from figure VI.1, the access component had one of the best perceptions in the characterization workshops in the three countries (topped only by the impact component in Uruguay). In fact, most participants in those workshops insisted that officials in agricultural institutions have the hardware and software they need to carry out their tasks, although they may often not have the desired technical quality. Moreover, there are still some variables relating to ICT access that pose challenges for public agricultural institutions, the principal one being the Internet (see figure VI.5).

Figure VI.5

Perception of progress with the ICT access component in public agricultural institutions



Source: Prepared by the author from the results of the characterization workshops

In the three countries examined, the greatest weaknesses under the "access" component relate to the existence, relevance and use of the Internet in public agricultural institutions. Even in Uruguay, the country that revealed the best perception of the Internet, officials of public agricultural institutions reported that they have the Internet but that the information available is outdates or it is of no relevance for their daily work. They also said that this tool provides them with no feedback for management processes or decision-making, and does not allow for the handling of internal procedures.

While the general opinion among participants in the Costa Rica workshops was similar to that in Uruguay, the average perception in Paraguay was that public agricultural institutions do not have the Internet. Nevertheless, as discussed below, in Paraguay the perception among officials of the central public institution (MoA) differs from that of officials in the public service institutions.

Beyond their perception that the Internet is nonexistent or of little use, workshop participants perceived hardware and software as two additional ICT variables constraining the potential of public agricultural institutions. In the three countries examined, the perception was that only half of the officials of public agricultural institutions have access to the needed equipment (computer, printer etc.) and that only half of that equipment (or less than half in the case of Costa Rica and Paraguay) fulfils the needed technical requirements (speed, processing and storage capacity, etc.) for employees to carry out their daily tasks. Moreover, only half of that equipment has the necessary software and the required updates.

An important finding was the perception that the public agricultural institutions with a lower level of ICT development use these technologies primarily for purposes of central administration. In Uruguay and Costa Rica, officials of public agricultural institutions that provide services to the final client considered that they had better access to software and hardware than did officials of the central institution (MoA). Participants in the Uruguay workshop felt that the decentralized public institutions responsible for providing services to farmers have greater access to connectivity, hardware, intranet, websites etc. The same picture appeared in Costa Rica, except for the connectivity variable.

In Paraguay the situation is the opposite: although there are software and hardware constraints, ICTs are used primarily for purposes of the central institution. The same situation applies with respect to intranet. While officials of Paraguay's central agricultural institution consider that it has an intranet, with information that is moderately up-to-date and/or of some relevance for their daily work, employees of the decentralized service institutions insisted that their institutions did not have this tool.

It is common for institutions at the early stages of ICT development to use these tools primarily for management and administrative purposes, as digital agendas generally begin with the promotion of ICTs in financial and accounting systems, operations management systems, personnel administration systems, inventory management systems, logistics management systems, etc.

Nevertheless, placing ICTs at the service of management and administration delays their impact on the institutions' final clients. The officials of public agricultural institutions who have the greatest contact with clients are those working in departments such as extension, training, marketing, and veterinary services. As they have a better knowledge of their clients' needs and as they also have a more developed culture of knowledge management, these are the officials who have the greatest potential for speeding the construction of a digital culture within their institution, and of putting ICTs to use with positive impact on end-users.

Box VI.3

Websites of public agricultural institutions

The "Outlook for Agriculture and Rural Development in the Americas", published in 2011 by ECLAC, FAO and IICA, includes a special chapter on the use of ICTs in agriculture. That report notes that the great majority of websites of public agricultural institutions in LAC have the following limitations:

- Contents are organized according to the administrative structure of the institution and not the categories of knowledge.
- Updating is limited to posting news items about the sector or senior ministry officials.
- Webmasters are not well-versed in the technical issues for which their institution is responsible.
- Websites do not have a mobile version.
- Websites do not allow paperwork or transactions to be conducted online.
- Websites fail to take advantage of the possibilities to interact with end-users.

Although the websites of public agricultural institutions in LAC are far from being knowledge management spaces for end-users, there have been some significant experiments in Colombia, Uruguay, Mexico, Chile and Brazil.

Source: Prepared by the author from the results of the characterization workshops

One of the variables that the experts consider of greatest importance for the impact of ICTs in public agricultural institutions is the interoperability of ICT tools. According to the perceptions gleaned in the workshops, while many of the software programmes for the management and administration systems of public agricultural institutions in Uruguay are interoperable, this is not the case in Costa Rica and Paraguay. This means that the ICT systems used by public agricultural institutions in those two countries, and the business processes they support, cannot exchange data or share information and knowledge.

As to websites, workshop participants in the three countries reported that all public agricultural institutions have a virtual space for knowledge management, generally in HTML format. However, while participants in Uruguay and Paraguay considered that most of the contents or services of these websites were up to date, readily accessible, and moderately useful to their clients, participants in Costa Rica felt that the contents are neither accessible nor useful.

3. Use of ICTs in public agricultural institutions

One of the factors limiting the impact of ICTs in public agricultural institutions is the little use that is made of them. This was one of the components cited as being the least advanced in the three countries examined, as can be seen in figure VI.1. Although institutions may have access to the required ICTs, they often fail to make use of them in their processes because of the lack of an institutional culture, inadequate user skills, i.e. ICT tools were developed without taking into account the needs and characteristics of officials and clients, etc.

Of the three countries studied, Uruguay reveals the best perception of ICT use in public agricultural institutions. In contrast to Costa Rica and Paraguay, participants in the Uruguay workshops generally perceived that public agricultural institutions in their country were not lagging significantly in any variable related to ICT use; indeed, they felt that there had been significant progress in the use of ICTs both in internal processes and in providing technical assistance to clients.

Even in countries that are most advanced in ICT matters, the officials of central public institutions (MoA) make the least use of ICTs as a tool for certifying documents and processes. It is interesting to note that in Uruguay, while officials of the decentralized public agricultural institutions and the ICT policymaking bodies consider that they are using electronic signatures as a tool for authenticating and validating documents, officials of the central public agricultural institution (MoA) report that they are not yet using ICTs for this purpose. As the bulk of the paperwork that private agents perform involves certification of documents in the MoA, which does not offer the possibility to certify them via ICTs, all the private participants in the workshops declared that they have not been able to certify documents or processes using ICTs.

The majority of participants agreed that some efforts were being made to use ICTs for certifying documents and processes, but said that those efforts were confined to creating virtual platforms for downloading and completing forms, accessible via usernames and passwords given by the institution. They insisted that without paper documents it was impossible to obtain certification.

At the initial levels of ICT development, officials of public agriculture institutions may consider that they are making efforts to incorporate these tools into their processes. However, this perception is not shared by their clients. This situation pertains particularly in Paraguay.

Box VI.4
Principal uses of ICTS in public agricultural institutions in Uruguay

Workshop participants generally perceived that public agriculture institutions in Uruguay are using ICTs for:

- Certain of their management and administrative systems (financial and accounting systems and operations, personnel, inventory and logistics management).
- Responding to certain procedures and services requested by external users (online service centers, downloadable forms, reception and sending of digital documentation, file tracking, online payment, etc.).
- Constructing and disseminating institutional knowledge, but not for compiling information.
- Publicizing certain of their products and services.
- Compiling and sharing information and knowledge that private agents can subsequently use for taking decisions about production, but not about markets.
- Capacity-building.
- Facilitating coordination with public sector players but not with private stakeholders within or beyond the agriculture sector.

Source: Prepared by the author from the results of the characterization workshops

Officials of the central institution and those of the decentralized public agricultural institutions in Paraguay considered that ICTs were being used to some extent for relating with external users and clients (paperwork, primarily). Yet, when these results are compared with perceptions of the ICT policy groups and academic and private representatives in Paraguay, great discrepancies emerge: in fact, all the members of those groups considered that public agricultural institutions did not have ICT tools for responding to procedures and services requested by external users (online service centers, downloadable forms, reception and sending of digital documentation, file tracking, online payment, etc.).

At intermediate stages of maturity, the agricultural institutions most involved in service provision (which generally enjoy greater institutional autonomy as well) are not only increasing their use of ICT for internal management but are also the first to use these tools to compile and share information that can be used for production and marketing decisions.

In Costa Rica, differences of perception between officials of public agriculture institutions and private users are not as marked as in Paraguay. However, there seems to be a discrepancy between the perception of officials of the central agriculture institution (MoA) and those of the decentralized institutions.

Officials of the decentralized agricultural institutions seem to feel that ICTs are being used to a significant extent not only for internal management (financial and accounting systems and operations, personnel, inventory and logistics management) but also for compiling and sharing information and knowledge that private agents can subsequently use for taking productive decisions (satellite imagery, GIS, meteorology, production costs, good practices, technology etc.) and market decisions (international prices, domestic prices, stock levels, harvest outlooks, trade statistics, transportation etc.). Nevertheless, this view is not shared by officials of the MoA, who consider that information and knowledge compiled through ICTs are not used by private agents in taking decisions.

Box VI.5

The *agromensaje* project in Costa Rica

In 2011 the Ministry of Agriculture of Costa Rica and the Costa Rican Electricity Institute (ICT), in collaboration with IICA, implemented a project known as *Agromensajes* (“Agro-messages”) to provide timely and relevant information that producers, traders and consumers can use in making decisions about their agricultural activities.

In response to a text message from a cell phone, the system will provide information on agricultural market prices (with other types of content to be included shortly). In contrast to other systems, *Agromensajes* does not require lists of codes: all that is necessary is to include the common name of the product (e.g. tomatoes).

The implementation and use of *Agromensajes* has been facilitated by various factors, including the coverage of telecommunication services in the country, the partnership between MoA, the telephone service provider and technical cooperation institutions (IICA), ease of use, the quality of the market information, and the cost of the service (US$0.005).

Source: Ministry of Agriculture of Costa Rica

Some of these differences of perception may originate in the fact that MoA officials are not familiar in detail with the impact of the initiatives of extension workers, trainers or marketing officials and consequently may feel that efforts to collect and disseminate information are unproductive. Moreover, MoA officials consider that, although ICTs have been incorporated into some processes of internal management, handling of procedures and institutional management, this has had no impact on the end-user.

4. Impact of ICTs in public agricultural institutions

Because the incorporation of ICTs in public agriculture institutions of LAC is relatively recent, there are few available examples of positive, concrete and measurable results. On the contrary, most institutions are still in the process of learning and adaptation. Moreover, it is difficult to observe concrete results because many of the initiatives for increasing the use of ICTs in public agricultural institutions lack homogeneity and long-term sustainability, in the absence of a central strategy for a digital agenda or electronic government.

With a view to identifying interim progress in this area, however, the workshops included a section on perceptions about the current status of key variables reflecting the impact of ICTs in public agricultural institutions. The main results are summarized in figure VI.6 and are described below.

Where the use of ICT is more mature, as in Uruguay, there is a high perception of positive impacts from the use of ICTs in public agricultural institutions. As in most of the previous cases, Uruguay has the best perception of the three countries analyzed as to the current impact of ICTs. Generally speaking, workshop participants said that, thanks to the use of ICTs, public agricultural institutions have been able to increase (if only slightly) the geographic coverage of their products or services, reduce (again slightly) the time and cost of internal management processes, and boost the quantity and quality of the products or services they offer.

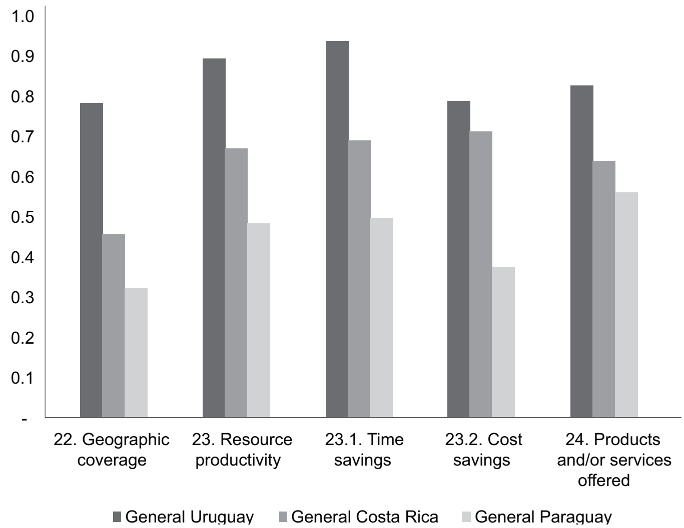
At intermediate stages of ICT maturity, as in Costa Rica, where it is the decentralized public institutions that make greatest use of ICT in providing services, these are the institutions that have the best perception of their current impact. As with the variables referring to the use component, officials of decentralized agricultural institutions in Costa Rica seem to have a more positive perception than do those of the central institution

(MoA) as to the current impact of ICTs in the institution. They consider that ICT use has allowed them to expand the geographic coverage of their products and services and to reduce internal management costs, while officials of the Central Ministry do not see things this way.

With respect to geographic coverage, technical staff of the extension, training and marketing services consider that connectivity in remote rural areas has made it possible to reach new groups of farmers, although they recognize the need to adapt teaching methodologies to the new online training techniques.

Figure VI.6

Perception of the current impact of ICTs in public agricultural institutions

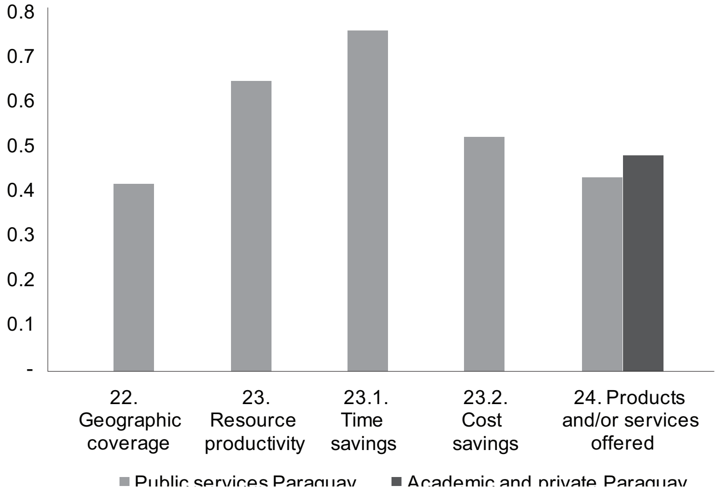


Source: Prepared by the author from results of the characterization workshops

Costa Rica's public agricultural institutions seem to be further advanced along with the ICT learning curve than those in Paraguay. In Costa Rica, the general perception is that the initiatives taken by public agricultural institutions have still not produced much in the way of positive results, as ICT use has not led to any increase in geographic coverage or any reduction in internal management process times and costs. On the positive side, participants did consider that public agricultural institutions had increased slightly the quantity and quality of products and services they offer, thanks to the use of ICTs.

In Paraguay, workshop participants considered that the little use made of ICTs in public agricultural institutions has not contributed to expanding geographic coverage or the quality and quantity of products offered (see figure VI.7). On the contrary, they felt that these technologies were increasing costs and time involved in internal management processes. Thus, it may be said that in the initial stages of ICT implementation, as in Paraguay, the situation is similar to that with the use component: while officials of public agricultural institutions may consider that ICTs have already had an impact in their processes, this perception is not necessarily shared by their clients.

Figure VI.7
Paraguay: perception of the current impact of ICTs in public agricultural institutions



Source: Prepared by the author from results of the characterization workshops.

5. Factors conditioning the future impact of ICTs in public agricultural institutions

The factors that will condition the future impact of ICTs in public agricultural institutions may well be the biggest challenge facing the region in the digital area. The allocation of technical and financial resources for building a culture of digital literacy or knowledge management, together with the development of ICT tools that can meet user needs, are among the principal outstanding tasks.

Among the countries examined, Uruguay again stands at as having the best perception of the future impact of ICTs in public agricultural institutions. Yet, not all variables were perceived positively. In fact, the general perception was that Uruguay's public agricultural institutions are lagging seriously behind in digital literacy because institutional policies in this area are not backed by sufficient technical and economic resources. Moreover, there is a consensus that the ICT-based systems, platforms and tools available to public agricultural institutions were not developed with a view to the knowledge, technical assistance, communications and other needs of officials in those institutions, nor those of external users.

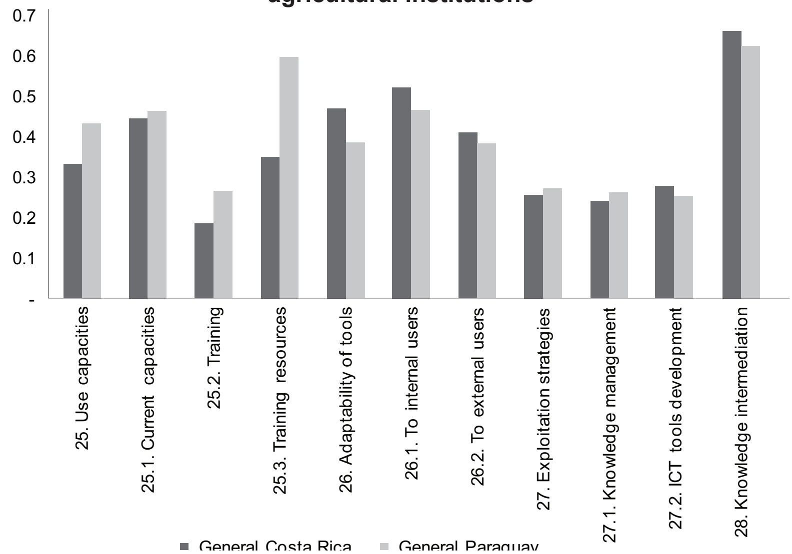
While their ICT initiatives are at different stages of development, in both Costa Rica and Paraguay workshop participants had very similar perceptions about the factors conditioning the future impact of ICTs in public agricultural institutions (see figure VI.8). The majority felt that officials of these institutions do not have the knowledge needed to use ICTs effectively, and that knowledge in turn is difficult to develop because digital literacy policies do not have sufficient technical and economic backing. As a result, public agricultural institutions are not generating their own knowledge through the use of ICTs.

A positive note in both countries is that, while public agricultural institutions do not generate their own knowledge through the use of ICTs, they are using these tools to compile and systematize information and knowledge from other primary sources, and subsequently to disseminate it.

In Costa Rica, the perception of factors conditioning future impact is more flattering in the decentralized institutions than in the central ministry. In contrast to the MoA, Costa Rica's decentralized agricultural institutions considered that there is indeed a strategy for developing ICT tools, one that takes account of clients' needs and demands, and that, once developed, those tools are used for serving internal and external users alike. In Paraguay, the perception seems to be the contrary, as the central institution is the one that has the most favorable conditions for the future impact of ICT in its processes (with the exception of the training variable).

In Uruguay, although the perception of all variables of current ICT impact was greater in the decentralized public institutions, some of the future impact variables were better perceived in the MoA, particularly those relating to training in the use of ICT and the adaptability of ICT tools to user needs.

Figure VI.8
Costa Rica and Paraguay: perception of the future impact of ICTs in public agricultural institutions



Source: Prepared by the author from the results of the characterization workshops

D. Proposals for resolving the bottlenecks identified

Boosting ICT access, use and impact in public agricultural institutions requires to promote agriculture as a priority sector in digital agendas. The first step in this direction is to persuade the authority responsible for e-government or the digital agenda of the benefits to agriculture and to the economy as a whole that will flow from early inclusion of public agricultural institutions in the e-government strategy.

It is also essential that the authorities responsible for the digital agendas should understand that incorporating ICTs through "use" or utilitarian approaches in public agricultural institutions will serve not only to enhance the profitability and productivity of their economic and human resources, but will also bring new players into technical assistance, expand the geographic coverage, and offer products and services better suited to clients' needs.

As well, there is an *a priori* need to boost digital literacy and data skills among employees of public agricultural institutions. Electronic government strategies favor institutions in health care, education and public finances not only because these are the fields that have the greatest short-term impact on end-users, but also because these institutions generally have employees who are better trained in the use of ICT tools. Consequently, if agriculture is to be promoted as a priority sector in digital agendas public agricultural institutions will have to construct and implement a policy for digital literacy at all levels, i.e. it cannot be treated as purely a matter of technologies. Moreover, ICT projects should no longer be conceived as simple pilot experiments; rather, they should aim to find sustainable and scalable solutions that will benefit the majority.

More specifically, participants in the workshops for characterizing access to ICTs and their use and impact in public agricultural institutions in Uruguay, Costa Rica and Paraguay identified the following bottlenecks and their respective strategic actions.

1. Regulatory and institutional framework

a. Unfamiliarity with the national ICT strategy and lack of institutional articulation for implementing e-government procedures

Although their countries are not at the same stage of maturity in their ICT strategies, workshop participants in Uruguay and Costa Rica agreed that the principal limitation with respect to the ICT regulatory framework is unfamiliarity with the national ICT strategy on the part of officials in public agricultural institutions and the lack of articulation of initiatives for implementing e-government procedures in the agriculture sector.

In Uruguay, discussions revolved around the constraints that public agricultural institutions face in adopting digital government procedures. Eventhough these procedures are defined by the ICT policy body (AGESIC) there has been a lack of coordination among public institutions that shows up in the overlapping of ICT responsibilities and activities within the same unit and among different units.

As proposed solutions, workshop participants discussed the idea that, once AGESIC has established its e-government policies, a coordinating body should be established with representatives from each agency within the MGAP, who would be responsible for implementing the e-government policies of AGESIC, coordinating with all internal stakeholders to improve management. This body would report to AGESIC, which in turn would be responsible for supervision and auditing.

This body should have sufficient hierarchy to implement policies, and sufficient economic and technical resources to conduct training activities. One of its main responsibilities would be to ensure interoperability of data and to manage the tools so as to produce solutions that will meet clients' needs and constraints.

In Costa Rica, workshop participants considered that in general the main limitations under this component were: (i) unfamiliarity with the current status and digital government commitments throughout the sector; (ii) lack of leadership in the agricultural sector for articulating the actions of all stakeholders in promoting digital government; and (iii) institutional links for digital government in the agriculture sector that are not sufficiently strong to carry out the necessary actions. As a result, the sector is not promoting technology projects or services to improve processes, and there is no interoperability between the systems of different institutions in the sector.

In terms of solutions, the proposed first step was to raise the visibility of digital government issues in the internal systems of public agricultural institutions, something that was thought quite feasible in the short term. Over the medium term (because of its greater technical and political difficulty) it was suggested that the commitment of the responsible minister should be strengthened and institutional linkages reinforced for each agricultural subsector. As well, agriculture-specific e-government projects were recommended in key institutions for rural development.

b. Failure to disseminate standards and rules and low use of electronic signatures

In Paraguay, the main problem identified was that, although there is a general regulatory framework governing the validity of electronic signatures, including digital signatures, it is not widely used. This is due primarily to the failure to publicize the existence of that framework, the lack of conditions for implementing it (procedures, economic resources, technical resources) and unfamiliarity with its functional and security aspects on the part of users

To address this unfamiliarity with the regulatory framework, workshop participants proposed the following: (i) follow the guidelines in national policies, i.e.the ICT Master Plan; (ii) generate accessible websites with full information on the topic; (iii) make use of the mass communications media; and (iv) prepare an awareness campaign about electronic and digital signatures, targeted at different public and private audiences.

To improve conditions for implementing the regulatory framework governing electronic signatures, it was suggested that policies for hardware and software security should be implemented, procedural manuals should be prepared, and the institution's annual budget should make provision for covering implementation and maintenance costs.

To enhance knowledge about the use and security of electronic signatures, the group had no easy answers to offer. It was suggested that, despite the high economic cost, the greatest impact may be from training programmes differentiated by type of user (user profile, technical profile, general public).

2. Access to ICTs

a. Lack of Internet access in rural and isolated zones

In contrast to Uruguay and Costa Rica, where virtually all urban areas (and a high proportion of rural zones) have Internet access, such access is missing in a large portion of Paraguay's national territory. According to ITU figures, only 0.5% of the country's population has a personal computer and only 2.5% uses the Internet. Access to these ICT tools is even lower in rural and marginal areas.

Consequently, workshop participants considered that the uneven distribution of Internet accessibility across Paraguay was the main factor limiting access to ICTs. The low rate of Internet access is due primarily to the fact that Internet service providers gear their services to profitability considerations, ignoring (or overcharging in) regions that are remote from population centers.

Measures proposed to boost the coverage (or reduce the prices) offered by Internet service providers include tax exemptions for firms that provide service in isolated regions, public-private agreements or contracts for erecting fiber-optic towers and cabling, universal service funds and implementation of overseas connections (which would require renegotiation with MERCOSUR).

b. Outdated and poorly functioning intranet and Web facilities in public agricultural institutions

As Uruguay and Costa Rica have more highly developed basic ICT facilities (nearly nationwide Internet access), workshop participants considered that the principal limitations on ICT access in public agricultural institutions had to do with their intranet and web pages.

In Uruguay participants considered that the web pages of public agricultural institutions were not fulfilling their role because there was no single website management unit within the institution, meaning that the distribution and presentation of contents was not standardized. Not only do current and outdated contents coexist, but there is no clarity as to which institution is responsible for updating and publication. As a result, contents are disorganized and obsolete, and difficult to access.

To resolve these constraints, it was proposed that a national entity (e.g. AGESIC) should be designated to define a standard for public institutional websites, along with an entity in the agricultural sector that could standardize and organize the presentation of contents for the various executing units and divisions (according to the management model: centralized, distributed, or mixed). There were also suggestions to establish homogeneous criteria for assigning responsibility for the input and update of information in each of the institutions, and to facilitate access to contents through search engines that are intuitive, visible and efficient. To improve feedback between technicians and end-users of information, participants proposed the use of 2.0 technologies.

In Costa Rica participants argued that the obsolescence and poor functioning of public agricultural institutions' intranets and websites could be laid to the fact that ICT tools are not widely understood by the institution's authorities, there is no overall ICT policy for the sector, and the sector's ICT needs are not defined. Thus, many decisions about the ICT tools to be developed (as well as the obligation to use them and keep them updated) depend on the will of the authorities and their level of understanding and commitment to the issue.

As a solution, participants in the Costa Rica workshop agreed that the first activity should be to raise awareness of the importance of ICTs and the impacts they can have on the institution (particularly for the authorities). This will require creating forums (actual and virtual) for discussing the potential benefits of ICTs in the institution's processes, and to retrieve methodologies that can justify ICT projects in terms of cost and benefits. Participants felt it was also important for countries (or institutions) that have advanced further in this area and that have achieved positive results from the use of ICT in their processes to disseminate their experience and lessons learned.

As a second point, it is essential to construct (or adapt) the methodology to define the ICT needs of public agricultural institutions, and this could be the first item of work for the ICT-AgricultureRoundtable (an interagency body of the agricultural sector responsible for the ICT issue). Not only should the work of that ICT-Agriculture Roundtable be institutionalized but its members should be given training so that they can formulate, implement and manage ICT projects that will close the existing gaps.

3. Use of ICTs

a. Limited use of ICTs in interagency coordination

In Uruguay, one of the primary constraints under this component was the low use that public agricultural institutions make of ICTs for facilitating coordination with other sector organizations or other ministries (virtual networking, videoconferencing, shared virtual documents, institutional databases, virtual institutional memories, digital libraries, etc.).

Workshop participants generally felt that the situation results from complementary limitations. First, institutions are assessed against standards and indicators of their own performance, regardless of how they work with other institutions. Some institutions, indeed, have a compartmentalized organizational culture, which means that some individuals will ignore the institution's coordination policy. Second, there is a lack of digital culture among the authorities of agricultural institutions, which makes it impossible for them to appreciate the scope of ICT tools.

To promote greater interagency coordination within the agriculture sector, there were proposals to establish performance indicators that place value on horizontal management and coordination and to institute methodologies for assessing team performance. There were also calls to define and establish robust processes to generate cross-cutting policies that would be clearly understood by institutions and individuals.

To create a new culture of ICTs and knowledge management in public agricultural institutions, training in processes, management and ICTs was suggested at all levels as a way of increasing the use of these technologies.

b. Although this should be one of their most intuitive uses, ICTs are rarely employed in training

In the public agricultural institutions of Costa Rica, ICTs have yet to become a training instrument because institutions have no policy or lack the technological resources and also because of a lack of commitment on the part of employees.

In institutional terms, none of the existing policies provides for or requires procedures to make ICTs a strategic component. Moreover, many institutions have neither the equipment nor the financial resources required to provide training through ICTs.

Beyond these institutional constraints, moreover, there is a lack of motivation on the part of employees in public agricultural institutions to assume training commitments and to revise (or propose) training models for reaching more clients. To date, training efforts have been inadequate, inappropriate, erratic, improvised and frequently designed according to individual perceptions without reference to an institutional strategy.

To resolve institutional and individual shortcomings, participants in the workshops proposed that training should be a permanent feature of institutional programming, so that the authorities and their employees can be evaluated against results obtained in this activity. This would encourage the search for new tools (including ICTs) that would improve training outcomes.

If the intent is to have public agricultural institutions basing their training programmes on ICTs, then training will be needed within the institutions to instill awareness of the potentials and uses of the main ICTs in these processes (functional literacy).

Although they recognized that this is more difficult to achieve, participants in Costa Rica thought it was essential to enhance the quantity and quality of human and technological resources available for training. Training managers must have the required equipment (hardware and software) as well as contents development and education specialists to improve the results of these processes.

c. Lack of ICT-based services and procedures

In Paraguay, the main constraint under this component is the impossibility of conducting services and procedures via ICTs in public agricultural institutions. The reasons for this are: (i) there are no institutional policies or regulatory framework requiring the use of ICTs to improve service; (ii) the technical infrastructure (networks, servers, Internet, workstations and information systems) is deficient; and (iii) public servants and end-users alike lack training and awareness.

Workshop participants agreed that before defining a new regulatory framework for institutionalizing ICTs, an assessment of current standards, needs and resource availability should be performed, as a basis for defining suitable ICT policies.

To improve the technological infrastructure, an institutional master plan for ICTs will have to be developed (as part of the overall ICT Master plan) setting out the dimensions for equipment, networks, resources etc. In addition to the institution's own resources, funding will have to be obtained through international organizations, donations, partnerships with suppliers, etc.

With respect to ICT training and awareness raising, a plan should be prepared to address these topics in a continuous manner, both for internal employees and for end-users, after which funds for implementing it will have to be found.

4. Impact of ICTs

a. Lack of an institutional policy for digital literacy and knowledge management

Reflecting the reality in the great majority of countries of the region, participants in the workshops in the three countries examined agreed that the lack of an institutional policy for digital literacy and knowledge management (or the shortage of technical and economic resources) is the principal factor constraining ICTs in public agricultural institutions. Generally speaking, participants in the three workshops felt that applying more advanced technological solutions would make sense only if users (primarily internal users) are properly trained to understand, interpret and work with ICT tools.

One of the principal causes cited was institutions' lack of ICT training plans, reflecting the scant interest in the issue on the part of the authorities and of employees. To overcome these limitations, the workshops proposed as an initial step (recognizing that this is difficult to do) the construction and implementation of awareness raising programmes for the authorities and for employees, to persuade them of the potential impact of this technology in each of the institution's processes.

The next step should be to prepare a policy for the functional digital literacy of all employees in public agricultural institutions, for subsequent implementation (inventory of technical and economic resources, job profiles and short and long-term training plan), monitoring and evaluation. In these tasks it will be important to arrange technical and financial support from cooperation institutions for sharing experience and assisting in implementation.

At the same time, incentives should be offered for personnel to undertake training and performance appraisals should be used in allocating training. This will require the preparation, standardization and application of ICT training programmes that are based on institution-wide rules and criteria, and not left to the discretion of managers or senior authorities.

To improve information and take better advantage of ICT training opportunities, the new equipment acquired should be distributed according to the real needs of technical staff, and information on training should be distributed and disseminated through newsletters and bulletin boards (physical and digital), intranet, webpage, institutional radio, virtual channel, etc., so that all employees of the institution will have the appropriate information.

E. Final considerations

Aware of the potential impact that ICTs can have on management and administrative processes and on technical assistance, many of the public agricultural institutions of LAC have been making efforts to incorporate these technologies into their work. Yet, the actions pursued by the central public agricultural institutions (MoA) designed to strengthen ICT access and use will not have the desired homogeneity, sustainability and long-term impact unless there is a stronger electronic government strategy or digital agenda. The lack of a policy requiring all institutions to conduct internal processes and offer services through the use of ICTs could jeopardize the progress achieved by the MoAs, since changeovers in government authorities or ICT department directors could cause shifts in the institution's digital course.

Yet, the mere existence of an e-government strategy or a digital agenda does not guarantee the homogeneity or impact of ICT efforts in public agricultural institutions. In efforts to foster ICT access and use in public institutions it is common to give priority first to the fields of health, education and public finances, leaving agricultural institutions for a later stage.

In contrast to what many people might think, the lack of investment in ICT tools (hardware, software, Internet, Web, cell phones etc.) is not the main reason why public agricultural institutions in Latin America are lagging behind in digital matters. Although the absence or obsolescence and the low functionality of these tools are important limitations, these do not explain why farmers perceive no impact from the use of ICTs in public agricultural institutions.

End-users' perception that ICTs have little impact is due primarily to the fact that it is only at the intermediate stage of maturity that the agricultural institutions mainly responsible for service delivery begin to make increased use of ICTs in their internal management and employ ICTs to compile and share information of the kind that can be used for taking production and market decisions. This is a very important consideration, recognizing that it is the technical staff of service institutions (research, extension, training, marketing etc.) who have the greatest knowledge of end-users' needs and the greatest capacity to integrate ICTs into the products they offer those users.

At the initial stages of maturity, ICT tools are used for purposes of management and administration in the central institution (MoA), primarily because e-government strategies and digital agendas start with introducing ICTs into administrative and management systems, leaving to a later stage those institutions that serve end-users.

If the intent is to boost the positive impacts of ICTs in the workings of public agricultural institutions it is essential that national digital agendas should include, from the outset, the technical staff who have greatest contact with end-users (extension, marketing, education, plant and animal health, laboratory services etc.) instead of relegating ICTs exclusively to administrative and management purposes.

Generally speaking, any process of institutional modernization undertaken to boost the impact of ICTs in public agricultural institutions must treat the end-user as the central objective. To this end, agricultural institutions must have policies and strategies that will promote the exploitation and development of ICTs as part of their day-to-day processes, making the topic one of mandatory and institution-wide concern. These policies and strategies must guarantee that developments of ICT tools will take into account the needs and demands of end-users, and that both the technicians and the users of those technologies will have the knowledge needed to exploit them fully.

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