



Review [Revisión]

TECHNOLOGY TRANSFER IN AGRICULTURE: THE MEXICAN EXPERIENCE †

[TRANSFERENCIA DE TECNOLOGÍA EN AGRICULTURA: LA EXPERIENCIA MEXICANA]

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SUMMARY

Background: Mexican primary sector needs a repositioning to meet the challenges associated with society's demands in the new millennium. Understanding the past is paramount to learn from mistakes and adapting more swiftly to upcoming demands. **Objective:** This review aimed to describe a historical overview of economic developmental models and technology transfer strategies to modernize Mexico's primary sector. Additional information on economic development and technology transfer policies from other Latin American countries provides a contextual perspective. **Results:** Mexican economic models as early as the XIX century provide the importance of technology transfer to the primary sector. However, they did not support scientific research as a source of innovation. From the 1950s onward, the need for scientific research to generate innovation and adaptation of new foreign technologies becomes evident in technology transfer schemes. Similar scenarios are found in several other Latin American countries. **Implications:** as a reaction to this need for innovation, Institutes of scientific research and extension were created in a global economic scenario dictated by the neoliberal economic model. Despite such progress, research and extension institutions have met with continued pressure from economic and political sources. Therefore, Mexican research and extension institutions need more financial support and long-term goals for improved outcomes. **Conclusions:** technology transfer strategies in Mexico have historically adapted to shifts in economic developmental models. There is a need for investing in scientific innovation, enhancing such investments with focused long-term goals. All these might meet the rapidly changing demands posed by the new millennium.

Keywords: Mexico; innovation; extension; development models.

RESUMEN

Antecedentes: El sector primario mexicano necesita reubicarse para alcanzar los retos asociados con las demandas sociales del nuevo milenio. Se debe entender el pasado para aprender de los errores y adaptarse rápidamente a las demandas por venir. **Objetivo:** Esta revisión describe un panorama histórico de los modelos de desarrollo económico y de las estrategias de transferencia de tecnología para modernizar el sector primario de México. **Metodología:** Información adicional en desarrollo económico y en políticas de transferencia de tecnología de otros países de Latinoamérica provee una perspectiva contextual. **Resultados:** Los modelos económicos mexicanos desde el inicio del siglo XIX proveen la importancia de la transferencia de tecnología al sector primario, aunque no apoyan a la investigación científica como fuente de las innovaciones. A partir de la década de 1950, la necesidad de investigación científica para generar innovaciones e investigación adaptativa de nueva tecnología extranjera se hizo evidente en los esquemas de transferencia de tecnología. Escenarios similares se podían ver en varios países Latinoamericanos. **Implicaciones:** Como reacción ante la necesidad de

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innovaciones, se crearon instituciones de investigación científica y de extensión en un escenario global dictado por un modelo económico neoliberal. A pesar del progreso logrado, las instituciones de investigación y extensión se han enfrentado a una presión continua de fuentes económicas y políticas. Sin embargo, las instituciones mexicanas de investigación y extensión necesitan mayor apoyo financiero y objetivos de largo plazo para lograr mejores resultados. **Conclusiones:** En México, las estrategias de transferencia de tecnología se han ido adaptando históricamente a los cambios de los modelos de desarrollo económico aplicados. Se requiere investigar la innovación científica que permita mejorar las inversiones enfocadas en objetivos de largo plazo. Todo ello podría acompañar las demandas rápidamente cambiantes que impone el nuevo milenio.

Keywords: Mexico; innovation; extension; development models.

INTRODUCTION

The contribution of agriculture to a country's development occurs naturally due to its importance to the overall economic dynamics (Trigo *et al.*, 2013). For instance, agriculture offers primary goods, delivers financial resources for the labor force and production processes, generates country dividends by exportation, transfers exceeding labor force at low cost to the industrial sector, and represents a market for manufactured goods by the industry (Cruz and Polanco, 2014). Agriculture further provides food for the ever-growing population, raising its demand for quality and quantity. In contrast, the primary sector faces many challenges: low profitability, near-poverty conditions for smallholder farmers, and natural resources deterioration. Finally, the agricultural industry changed the primary sector landscape, motivating the acquisition and application of more advanced technical knowledge and infrastructure (Rojas, 2015).

The sustainable growth and development of agricultural practices (production yields and productivity) are attainable if local governments deliver well-defined policies for this sector (Cruz and Polanco, 2014). These policies must contemplate subsidies, investments in research, preferential credit, crop insurance, bonding, infrastructure development, and technology transfer (Gómez-Oliver, 1994). Several authors agreed on the fact that technology transfer processes reside on use of improved agricultural inputs, up-to-date technology, and innovation (Gómez-Oliver, 1995; Jover, 1999; Muñoz-Rodríguez *et al.*, 2001; Barradas *et al.*, 2002; Leeuwis, 2004; Sabater, 2010; Ponce, 2013; Trigo *et al.*, 2013; Cruz and Polanco, 2014; Larqué-Saavedra *et al.*, 2014; CONEVAL, 2015; Rendón-Medel *et al.*, 2015; Amaro-Rosales and Gortari-Rabiela, 2016a; Solleiro *et al.*, 2017).

As the source of structural changes in society and the global economy, education has empowered the business sector since 2000 (Limaylla *et al.*, 2014).

Developed countries' growth remains firmly based on scientific and technological development, which straightens economic growth (IICA-GTZ, 2000). Vast evidence demonstrates that public policies with access to scientific knowledge and technology development can improve life well-being in many ways (Limaylla *et al.*, 2014) and increases the mean income (Muñoz-Rodríguez *et al.*, 2001). Appropriate and clear public technology transfer strategies allow improved agricultural practices by incorporating innovation at the production level. These strategies spawn from dynamic effects and surge to motivate the adoption of valuable information provided by human labor mobility, ultimately transmitting tacit knowledge and training (De Arteché *et al.*, 2013).

Despite the current understanding that scientific research and innovation provide a solid foundation for sustained socio-economic growth and development, this concept has not been adopted during Mexico's history, and perhaps, in most Latin American countries. This mistake in economic and technology transfer policies profoundly affected Mexico's development over the past two centuries. Therefore, understanding this mistake is paramount to support adequate socio-economic and technology transfer policies. This review aimed to describe a historical overview of economic developmental models and technology transfer strategies to modernize the primary sector in Mexico while contemplating some information from other Latin American countries to give a perspective on the geopolitical scenario at any given time.

TECHNOLOGY TRANSFER AND ITS IMPLICATIONS

Some interrelated concepts need an explanation to understand the process of technology transfer. New technology is the end-product of scientific research. Therefore, "scientific knowledge" is defined as an ordinate system of structured information that studies, investigates, and interprets natural, social, and artificial phenomena.

As an activity, the concept of science refers to a development process, its dynamics, and integration to the sum of activities with social impact (Leeuwis, 2004; Ardila, 2010; Gavito *et al.*, 2017). The definition of technology can be as broad or narrow as may be wanted (Sabater, 2010). Also, it is understood as the practical use of scientific knowledge (González-Sabater, 2011).

Furthermore, technology is conceived as a collection of tools made by humans, with the intent to perform a specific role. Technology also has instrumental practices, such as creating, fabricating, and using methods and machines, including all tangible and non-tangible materials in their social implications derived from the technical knowledge (Rammert, 2001), considered axis between the economic process and the social structure (Jover, 1999; Acevedo-Díaz, 2006; Ponce, 2013). To Gavito *et al.* (2017), the technology applies knowledge to generate new methods, processes, services, or devices. Moreover, technological innovation is the consequence of technology, the materialization of an idea into a product, equipment, or operative process (Jover, 1999). As scientists create new technology, they also create technological innovations. Technology as an endpoint applies to distinct equipment development areas, such as computers, industrial processes, commercial secrets, goods, exploration of natural resources, welfare processes, and services.

In the primary sector, technology represents the continuously evolving social processes, specific to agricultural activities, integrated by a set of technologies that allow the development of local technological capacities necessary to solve actual problems and meet a demand in the agricultural landscape (Ponce, 2013; Trigo *et al.*, 2013). Hence, science and technology are social processes influenced by the context in which they develop. In turn, their application demands careful estimation of their implications and social impacts (Jover, 1999). These complex inter-relationships between science, technology, and society constitute the techno-science, a systemic vision that has deployed traditional views of science (Acevedo-Díaz, 2006).

“Technology transfer” is a service that assists people with the acquaintance of improved agricultural methods and techniques. Technology transfer maintains a strict relationship with extension practices, a term created in the United States (Leeuwis, 2004; Ardila, 2010), albeit mentioned in Holland and Indonesia as “Voorlichting,” meaning to clear the path ahead

(Leeuwis, 2004). Hence, technology transfer represents one of the most effective mechanisms for accessing cutting-edge technologies. It also propels the interaction of the primary sector members with several institutions (e.g., scientific research, teaching and education, agroindustry) and strengthens agriculture competitiveness (Solleiro *et al.*, 2017). The impact of technology transfer is notorious: it increases production yields, generates more income, improves productivity, and ultimately leads to higher educational, living, and social standards (Leeuwis, 2004). The technology transfer and innovation policies for agriculture in Mexico relapse on the extension practice, comprising technical assistance, capacitation, and technological support (Amaro-Rosales and De Gortari-Rabiela, 2016b).

Agriculture growth has an essential role in producing food and other goods, playing a strategic role in our national, political, and economic agendas (Trigo *et al.*, 2013). The positive contribution of agriculture to economic growth supports its fundamental role in the economy (Cruz and Polanco, 2014); thus, technology is paramount for further positive economic input. Furthermore, the social return of knowledge in the Mexican primary sector is usually superior to the private sector profitability. Ultimately, the private sector becomes subsidized by the government due to the formation of human resources (public universities) incorporated by agricultural production systems. Due to the private sector's lack of incentives for innovation and technology transfer (Trigo and Kaimowitz, 1994; Muñoz-Rodríguez *et al.*, 2001) ultimately, this process (knowledge generation, knowledge bonding, and technology transfer) is viewed as a public cost.

In general, technology transfer is considered a linear process, based on generation/validation/transfer processes and the adoption of technologies, including scientists, extension agents, and agriculture or livestock producers as actors of such roles. Historically, the “linear vision” has dominated extension models in Mexico. Knowledge is generated and validated in realistic scenarios. “Technology validation” is an interface that associates the agricultural investigation system with the regional production systems, thus linking research with producers' practices (Galindo, 2004). Dubickisa and Gaile-Sarkane (2015) envisioned three perspectives to describe the relationship between innovation and technology transfer: technology transfer may include innovation; innovation may include technology transfer; also, innovation and

technology transfer may overlap. These relationships within these processes are also opportunities for further research (Figure 1).

Innovation requires adequate founding of technologies, usually derived from two sources: i) internal; technologies obtained from their research and development (R&D) Department; and ii) external, namely collaborations with other providers that have the technology available or are willing to collaborate toward developing the technology on-demand (Sabater, 2010). The company might be the technology receptor or provider (IICA-GTZ, 2000).

Once the technology is validated, it can be widely adopted. The concept of adoption is a mental process; the individual withholding the information for the first time reaches the point of accepting or abandoning the technology, under the influence of conditioning factors that contain three types of change: knowledge, attitude, and individual behavior (Galindo, 2004). The diffusion and transfer of innovations tend to begin with predefined innovations, which adoption has been considered desirable by the investigator in charge of the technology transfer. The technology transference and adoption has a sequence that, according to Lewis, derives from the model by Rogers (1962). It is constructed to a large degree with decision-making normative theories.

Rogers (1995) proposed a theory on decision making, based on fewer regulations that better reflects the facts in practice; it includes the following concepts: knowledge, persuasion, decision, implementation, and confirmation. Individuals do not adopt technology at the same time. There is a rate of promptitude, meaning that some are willing to readily adopt a technology, while others take longer (Rogers, 1995).

DEVELOPMENT MODELS AND TECHNOLOGY TRANSFER IN AGRICULTURE OF LATIN-AMERICA

The primary sector in Mexico and other Latin American countries has contributed to economic growth in many ways over the last 100 years. This sector's importance was initially high and crucial, while the industrial sector gained momentum and expanded its relative importance in the overall economic output. Nonetheless, if industrial consolidation is efficient enough, it is expected that the primary sector benefits by increasing incentives for exports of agricultural goods, sustaining domestic food supply (Cruz and Polanco, 2014, Solleiro *et al.*, 2017).

Several years after their independence, three models ruled the economic development of Mexico and other Latin American countries (Table 1): i) the primary-exporting model (PEM); ii) the importation substitution model (ISM); and iii) the neoliberal model (NM) (Trigo *et al.*, 1983; Delgado, 1995; Bejarano, 2002; Leeuwis, 2004; Acevedo-Díaz, 2006; Buitrago and Ricardo, 2006; Guillén, 2008; Ardila, 2010; Trigo *et al.*, 2013; Cruz and Polanco, 2014).

According to Trigo and Kaimowitz (1994) and Solleiro *et al.* (2017), organizations' installation to modernize agriculture through technology transfer in developing Latin American countries occurred after World War II as part of the ISM (Guillén, 2008; Vázquez, 2017). Initially, the emphasis was on agricultural modernization. It required limited or no scientific research, under the premiss of enough technology availability (generated locally or abroad) to significantly improve agricultural productivity; this fact excluded any input from local universities and research institutions (Trigo *et al.*, 1983; Trigo and Kaimowitz, 1994; Trigo *et al.*, 2013; Vázquez, 2017).

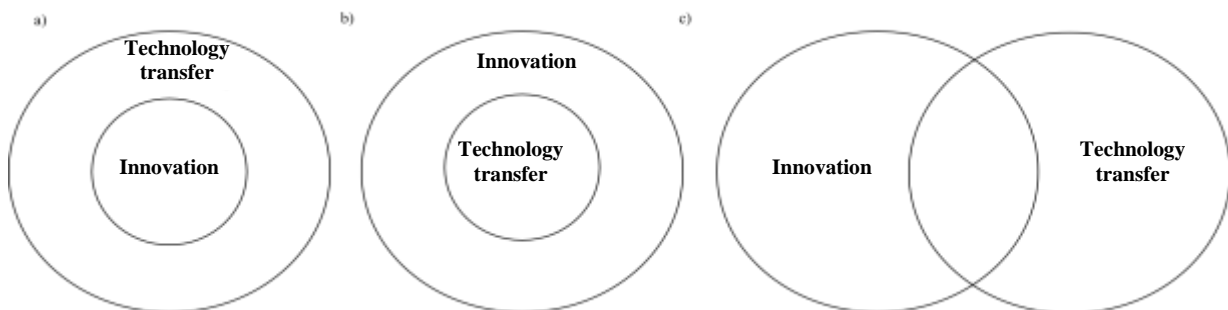


Figure 1. Three perspectives that supports the relationship between innovation and technology transfer. Modified from Dubickisa and Gaile-Sarkane (2015).

In the late 1950s, Latin American countries accepted the need to invest in national research capacities with the intent to “adapt” certain technologies from developed countries to local conditions (Trigo *et al.*, 1983; Trigo and Kaimowitz, 1994; Ardila, 2010; Trigo *et al.*, 2013; Solleiro *et al.*, 2017). Therefore, Latin American countries adopted the “Cepalino model,” with the concept of implementing something similar to the Marshall plan used to reconstruct European countries after the Second World War. The “Cepalino model” was aligned with Latin American economic policies, such as industrialization and substitution of importations based on the increased output of food supply by the primary sector (Bejarano, 2002; Guillén, 2008; Ardila, 2010). According to several authors (Ardila, 2010; Trigo *et al.*, 2013; Solleiro *et al.*, 2017), the technology transfer model that Latin America adopted contained many references to the Land-grant College model. The United States created this model following the “Morril Laws” of 1862 and 1890. Although later also included financial support from the private sector and agricultural associations, this system accepted federal and state funding.

In practice, this process was an essential step toward progress in economic, scientific, and technological terms for Latin America. By the end of the 1950s, most countries created semi-autonomous public research institutes; several had the strategic goal of performing extension and technology transfer activities. Most of their population lived in rural areas and relied on small-scale agricultural production for self-consumption. Thus, with some previous institutions' attempts, the “Instituto Nacional de Tecnología Agrícola (INTA)” was created in Argentina on December 4th of 1956 (Decree-Law 21.680/56). In 1947, the federal government in Mexico created the

“Instituto de Investigaciones Agrícolas (IIA),” renamed in 1961 as the “Instituto Nacional de Investigaciones Agrícolas.” This Institute, combined with the “Instituto Nacional de Investigaciones Pecuarias (INIP)” and the “Instituto Nacional de Investigaciones Forestales (INIF, launched in 1965), integrated the “Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP)” (Cadena-Iñiguez *et al.*, 2018c; SAGARPA, 2018). Thus, IIA and INTA were the first agricultural institutes in Latin America, with the mission to propel research and agricultural extension, with the ultimate goal of improving living conditions in rural areas (Durlach, 2005). After the foundation of INTA, this institutional model was replicated throughout Latin America by cooperative efforts between the U. S. government, private foundations (Ford, Kellogg's, Rockefeller, among others), and the International Development Agency and funding by the Inter-American of Development Bank. These institutes had similar goals when initially created. Some of these institutions remain active, although public and sectoral policies have changed drastically.

Another critical influence on institutional cooperation was the surge of international research systems. Three research centers were placed in Latin America: “Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT)” in Mexico, “Centro de Investigación Agrícola Tropical (CIAT)” in Colombia, and “Centro Internacional de la Papa (CIP)” in Peru (Ardila, 2010). Such research centers' development was a global public policy in the late 1970s led by the *International Service for National Agrícola Research*. This policy represented an important support to research and extension programs in Latin America (Oasa and Jennings, 1982; Guillén, 2008; Ardila, 2010; Trigo *et al.*, 2013).

Table 1. Economic models applied in Mexico and other Latin American countries.

Model	Main details	Period
Primary-Exporting	Exportation of agricultural goods, gold, and silver. Importation of manufactured goods for the elite	Early XIX century but most during 1918-1930
Importation Substitution	High inequality in Latin America. Technology transfer for agriculture and industry. Importations replaced by industrialization with national and foreign capital	1930- 1982
Neoliberal	Economic opening, financial deregulation, low governmental funding, and change in taxing policies by the International Monetary Fund. Projection of economies worldwide	1983-1990

WHAT HAPPENED TO THE MEXICAN ECONOMY AFTER THE IMPORTATION SUBSTITUTION MODEL?

The first evidence of technology transfer in Mexico date back to the pre-Hispanic period. However, during the Mexican revolution between 1911 and 1920, a mission formed by agricultural technicians traveled around the country to provide technical assistance (Amaro-Rosales and De Gortari-Rabiela, 2016b). Before the Second World War and the so-called “green revolution” in the 1950s, the government recognized the importance of extension programs for technology transfer in agriculture (Aguilar-Gallegos *et al.*, 2016). Under these historical precedents and the ISM, the government of President Lázaro Cárdenas promoted new land reforms (Gómez-Oliver, 1995). These reforms occurred throughout Mexico and Latin America, a movement influenced by the US agricultural extension model called “*Land Grant Universities*” (Ardila, 2010; Trigo *et al.*, 2013; Solleiro *et al.*, 2017). This model was implemented in 71 countries, and Mexico began in 1943. The model centered on promoting research and extension activities coordinated by federal governments, which ultimately relied on national agricultural research institutes to execute technology transfer (visiting and training model).

Moreover, governments and research institutes collectively established the priorities to guide extension programs. The visiting and training model had three fundamental characteristics: firstly, it was linear and unidirectional, where research goals motivated the experiments, with results shared later with no feedback between scientists and producers (Aguilar *et al.*, 2016); this system reinforced a hierarchical structure, where producers were solely assimilating the information (Amaro-Rosales and De Gortari-Rabiela, 2016b). The second program characteristic was a reliance on technology packages for widespread distribution, mainly exemplified by the diffusion of improved seeds. These strategies were fundamental cornerstones for the green revolution development (Muñoz and Santoyo, 2010). As the third characteristic of the model, either research and extension institutions formed an integrated network that offered both services and technology transfer. For instance, financial credit was available by Banrural, Fertimex provided fertilizers, and Pronase offered seeds. The contracts made all these companies the primary providers of agricultural inputs. Furthermore, another requirement to obtain credits was to contract a crop's insurance from ANAGSA; also, parastatal companies such as

CONASUPO or INMECAFE commercialized the production, contracted under a minimum price policy (Muñoz and Santoyo, 2010).

Based on the growing demand, the results of the governmental intervention using this agricultural extension model, led to the creation of public agricultural research institutes (Table 2), also supported by international foundations in Mexico by the late 1960s, thus leading to the creation of the Instituto Nacional de Investigaciones Agrícolas (INIA) (Muñoz-Rodríguez *et al.*, 2001; Ardila, 2010; Amaro-Rosales and De Gortari-Rabiela, 2016b). In 1985, INIA was fused with the “Instituto de Investigaciones Pecuarias (INIP)” and the “Instituto de Investigaciones Forestales (INIF)”, thus forming the “Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP).” This period was also marked by the creation of additional research programs and institutions in Mexico, such as the agricultural research and extension system of Mexico, the “Colegio de Postgraduados,” and the “Universidad Autónoma Agraria Antonio Narro” (Amaro-Rosales and De Gortari-Rabiela, 2016a). The same happened in other Latin American countries (Table 2). These institutions received intensive criticism over the years, since research has focused on questions that do not mirror the challenges faced on a daily basis by local producers.

During the ISM period (Bejarano, 2002; Buitrago and Ricardo, 2006; Guillén, 2008), Mexico faced steady economic growth due to extension and technology transfer policies in the primary sector. The Mexican Gross Domestic Product, primarily dependent on agriculture, grew 7% per year from 1940-1958. Afterward, there was a period of stabilizing economic growth, albeit the agricultural industry grew 9% annually and 6% from 1959-1981 propelled by the developing industrial sector (Gómez-Oliver, 1995; Cruz and Polanco, 2014).

The agrarian reform performed since Cárdenas' government was another vital factor that promoted the development of extension programs and technology transfer policies. This reform contemplated land distribution for collective use in units called “ejidos.” The impact was that the country reached auto-sufficiency in food production and supply by the mid-1960s (Cruz and Polanco, 2014). From president Miguel Alemán's government onwards, public policies strengthen agriculture production and industrialization, associated with the increased use of cutting edge technologies. The transfer of resources from

agriculture to the whole economic landscape helped the capitalization of economic units.

In contrast to the expectations, the programs implemented for economic development in rural areas became quite elitist as living proof of the ISM. Support was directed towards the industry and privileged the production of goods for consumers in urban areas, thus contributing to polarization and inequality growth between urban and rural populations. The majority of smallholder farmers that did not access financial credit or other incentives remained as self-consumption producers or migrated to other regions or urban areas. The rural emigration in the 1950s was dedicated to the agricultural industry demands but did not cause much migration, and most found work near their homeland. The later demand for the urban industry required moving to urban areas (Gómez-Oliver, 1995; Calva, 2004; Ardila, 2010; Trigo *et al.*, 2013; Cruz and Polanco, 2014; Solleiro *et al.*, 2017; Vázquez, 2017).

By the end of the 1970s, the elevated international credit interest rates (~43% year⁻¹) provoked a rapid increase in the external debt (Gómez-Oliver, 1995), leading to an economic slowdown in Mexico after decades of steady growth. This period also contemplates the beginning of the disarticulation and dismantling of agricultural policies. The first

indications of this trend were the decline in governmental credit to agriculture, diminished agricultural subsidies, and lower public investment in agriculture (Gómez-Oliver, 1995).

The impact of the NM reaches Latin America in the early 1980s (Table 1). With Miguel de la Madrid as president, Mexico installed a new economic developmental model for Latin America, thus following the Friedman doctrine of free markets and exportation-oriented economies. Many economies, including Mexico, abandoned the primary sector or chose inadequate developmental policies (Méndez, 1998; Cruz and Polanco, 2014). For Mexico, the NM's adoption brought parallelism of the primary sector's stagnation and the low economic growth that made producers vulnerable (Delgado, 1995; Calva, 2004). It was characterized by its anti-rural slant and its anti-interventionism and by which many rural development policies diminished.

The destruction of agricultural policies and the decline of the primary sector resulted from the Mexican economy's rapid opening, culminating in the *North American Free Trade Agreement (NAFTA)*, signed by the Mexican president Carlos Salinas de Gortari on December 14th, 1992. Under NAFTA's context, agricultural goods lost minimum price references, implying rentability

Table 2. Research institutions created in Mexico and other Latin American countries during the second half of the XX Century.

Name	Acronym	Country	year
Instituto de Investigaciones Agrícolas	IIA	Mexico	1947
Instituto Nacional de Investigaciones Agropecuarias	INIAP	Ecuador	1959
Fondo Nacional de Investigaciones Agropecuarias	FONAIAP	Venezuela	1959/1961
Instituto Nacional de Investigaciones Agrícolas	INIA	Mexico	1961
Instituto Nacional de Investigaciones Forestales	INIF	Mexico	1962
Instituto Nacional de Investigaciones Pecuarias	INIP	Mexico	1963
Instituto Colombiano Agropecuario	ICA	Colombia	1963
Instituto Nacional de Investigaciones Agropecuarias	INIA	Chile	1964
Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias	INIFAP	México	1985
Instituto de Ciencia y Tecnología Agrícola	ICTA	Guatemala	1972
Empresa Brasileira de Pesquisa Agropecuária	EMBRAPA	Brazil	1973
Instituto Boliviano de Tecnología Agropecuaria	IBTA	Bolivia	1975
Instituto de Desarrollo e Investigaciones Agropecuarias	IDIAP	Panama	1975
Instituto Nacional de Investigación Agropecuaria	INIA	Uruguay	1989
Dirección de Investigaciones Agrícolas	DIA	Paraguay	1992
Centro Nacional de Tecnología Agropecuaria y Forestal	CENTA	El Salvador	1993
Instituto Nicaragüense de Tecnología Agropecuaria	INTA	Nicaragua	1993
Instituto Nacional de Innovación y Transferencia de Tecnología Agropecuaria	INTA	Costa Rica	2001

References: Bejarano, 2002; Durlach, 2005; Acevedo-Díaz, 2006; Guillén, 2008; Ardila, 2010; Ponce, 2013; Trigo *et al.*, 2013; Larqué-Saavedra *et al.*, 2014; Vázquez, 2017, SAGARPA, 2018.

losses in the primary production and producers' buying power (Calva, 2004; Cruz and Polanco, 2014; Limaylla *et al.*, 2014).

The Mexican economic decline persisted under the NM. The combination of several factors (uneven economic competition, patronage, corruption, and lack of long-term thinking for public policies) and NM practices made the Mexican economic model unviable. Previous developmental policies became extinct or suffered abandonment. ANAGSA closed in 1990; Fertimex ended on the private sector in 1992; Banrural lost 75% of its structure by 1999, finally replaced by Financiera Rural in 2003. Conasupo gradually decreased its role of minimum price ruling for agricultural goods and stopped maize and bean acquisitions by 1998 (Muñoz-Rodríguez *et al.*, 2001).

The neoliberalism model promoted new extension and technology transfer approaches at national and international levels, albeit demanded reductions in local governmental research investment and privatization of selected public services. The Mexican government canceled programs and financial support to agricultural extension programs, thus discontinuing the “Dirección General de Promoción y Extensión Agrícola” and holding responsible the INIA and the irrigation projects called “Distritos de Riego” (Amaro-Rosales and De Gortari-Rabiela, 2016b).

Efforts begin to emerge by 1988 aiming to revitalize the Mexican agriculture due to the declining production. The reformulation of the extension system in early 1990's was the result of many factors. They originated from the government aim to revive the extension and technology transfer programs supported by the “Secretaría de Agricultura y Recursos Hidráulicos” (renamed as SAGARPA), through the “Dirección del Sistema de Extensión Agrícola” and research at INIA (Muñoz-Rodríguez *et al.*, 2001; Amaro-Rosales and De Gortari-Rabiela, 2016b).

In 1995, the “Sistema Nacional de Capacitación y Extensión Rural Integral (SINDER)” was created and integrated with the “Programa de Capacitación y Extensión (PCE)” and the “Programa Elemental de Asistencia Técnica (PEAT).” These programs focused on training and technical assistance with independent professionals hired with input from producers. An unfavorable outcome of this system was the surge of biased hiring, establishing clientelistic structures among organizations, reducing the extension program impact.

Another governmental strategy led to producers' participation in defining the priorities in research programs, aiming to presumed answers to the most demanding technical problems in Mexican agricultural settings. This new vision flourished in 1996 by creating the “Programa de Investigación y Transferencia de Tecnología (PITT)” as part of the “Alianza para el Campo” program. Farmers' foundations instrumented this program to ensure producers' input, integrating representative type producers under a Civil Association. The extension and technology transfer programs integrated research institutions, agricultural dispatches with federal funds, and state governments' activities. Approved budget by the “Consejo Estatal Agropecuario” allocated no more than 50% of the federal funding for research projects or technology transfer costs (Muñoz-Rodríguez *et al.*, 2001). This program, backed up by the PITT, showed some inconsistencies, such as the separation between technology development and validation from technology transfer processes to producers that may benefit from them. The generated innovations accumulated in the research centers and did not become available to producers. In sum, there was no systemic approach to monitor project development and its outcomes.

A similar program in Mexico was exclusively devoted to livestock production called the “Grupo Ganadero de Validación y Transferencia de Tecnología (GGAVATT)” was financed by the during the decade of 1990 and the decade of 2000 (Gallardo-López and Rodríguez-Chesani, 2011), process described by several authors (Barradas *et al.*, 2002; Eduardo *et al.*, 2002; Ponce, 2013). In 1970, members of the “Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP)” formed a group of producers to replicate the technology transfer system they developed for several years. An inter-institutional meeting of the livestock subsector in Veracruz state in 1990 aimed to display several experiences about technology transfer in livestock production. During this meeting, participants agreed to work with the GGAVATT model described by INIFAP, the program's foundation. Similarly, this model established programs in Tabasco and Oaxaca states. This effort also led to preparing documents (e.g., manuals) and training activities for professionals that would establish GGAVATT throughout the country.

This strategy was pivotal to popularize GGAVATT and allowed producers (Cattle and small ruminant keepers, beekeepers) to receive technical assistance directly on their farms. In turn, GGAVATT

professionals received support from research institutions to intensify the use of new technologies using validation and technology transfer agreements. From 1997 onwards, this model gave rise to the “Programa Nacional de Validación y Transferencia de Tecnología (PRONAVATT).” All GGAVATT associated producers in the country integrated the livestock component of PRONAVATT. GGAVATT professionals led the technical assistance component, integrated by the coordinators and all institutional components (research institutions, livestock subsectors, livestock associations, and representations of veterinarians and animal scientists). Although this institution has generated important innovations for the agricultural sector adopted by farmers, it has not complied the generation of added value to primary products and the strategies for farmers to access the various markets, generating higher income and contributing to innovation management.

Since 2001, agricultural policies' application became normalized in the “Ley de Desarrollo Rural Sustentable.” This law delegated policy application, research investigation, and extension to SAGARPA, which coordinated several institutions responsible for policy execution. The new extension policy delegated agent training to the “Sistema Nacional de Capacitación y Asistencia Técnica Rural Integral (SINACATRI),” with the main goal to execute and evaluate such training programs to the national level (Amaro-Rosales and De Gortari-Rabiela, 2016b). These processes centered agent training programs from the “Programa de Capacitación y Extensión (PCE)” and the “Programa Elemental de Asistencia Técnica (PEAT)” to give rise to the “Programa de Extensionismo y Servicios Profesionales (PRESPO).” This scenario included the SINACATRI, overviewed by both, municipal and state governments, with training provided by the “Sistema Nacional de Investigación y Transferencia Tecnológica para el Desarrollo Rural Sustentable (SNITT).” This institution coordinated training efforts for public and private institutional policies, for research endeavors, technology development, validation, and technology transfer. Unfortunately, there was no positive impact of these strategies due to the lack of true integration between SINACATRI and the SNITT (Amaro-Rosales, 2016b).

During the government of Felipe Calderón Hinojosa in 2007, derived from the National Plan of Development 2007- 2012 and in agreement with Article 14 of the “Ley de Desarrollo Rural

Sustentable” (DOF, 2007), the federal government presented the “Programa Especial Concurrente para el Desarrollo Rural Sustentable (PEC),” applied to the “Política de Desarrollo Rural.” In turn, the “Ley de Desarrollo Rural Sustentable” aimed to promote efforts with planning and prospecting, allowing sustainable development under a long-term vision; the fundamental premise that sustainable human development of the rural inhabitants and adequate management of natural resources. The PEC operated in an inter-secretarial manner within 17 dependencies of the federal executive cabinet.

Ardila (2010) described that under the “Desarrollo Rural y la Alianza para el Campo and the Dirección General de Servicios Profesionales para el Desarrollo Rural, SAGARPA” developed mechanisms to offer professional services to underdeveloped rural contexts. These initiatives gravitated to improve familiar agricultural settings and to strengthen rural organizations. Under this decisive government role, “Servicios Profesionales para el Desarrollo Rural” designed a working model that established evaluation and certification systems for companies and technical assistance firms. Furthermore, it established mechanisms to supervise and evaluate each agent's technology transfer performance (Gómez-Oliver, 1995; Rendón-Medel *et al.*, 2015; Amaro-Rosales, 2016b). This technology transfer setting led to high governmental subsidies, thus applying outsourcing for contracting to avoid workforce responsibilities and reduce fiscal burden (Gómez-Oliver, 1995; Rodríguez, 2010; Rendón-Medel *et al.*, 2015; Amaro-Rosales and De Gortari-Rabiela, 2016b).

Nonetheless, there are institutions in Mexico that operate for the past century to provide credit, guarantees, training, technical assistance, and technology transfer to the primary sector. These institutions operate as second-tier banks with their own heritage and offer their resources through intermediary financial institutions such as “Fideicomisos Instituidos en Relación con la Agricultura (FIRA)” and the “Fideicomiso de Riesgo Compartido (FIRCO).” Extension programs in Mexico and Latin America provide this service as complex public-private endeavors and, to a lesser extent, by public educational institutions under structural reforms modeled by the neoliberal economic system. As mentioned previously, the known policies (e.g., technology transfer, extension) result from complex organizational restructuring. This historical process describes the linear focus as a step of public monopoly in rural extension that leads to a crisis in the early 1980s,

derived from the consolidation of social and economic paradigms. These changes would facilitate the insertion of these countries in the global economy and to reduce public expenditures as a potential byproduct of such worldwide insertion (Gómez-Oliver, 1995; Méndez, 1998; IICA-GTZ, 2000; Calva, 2004; Ardila, 2010; Trigo *et al.*, 2013; Rendón-Medel *et al.*, 2015; Amaro-Rosales and De Gortari-Rabiela, 2016b; Solleiro *et al.*, 2017).

The presence of PSP was the result of demand from several institutions, non-profit organizations, and farmers themselves, with subsidies from public sources and the intervention of second-tier banks such as INCA Rural and FIRA. Recent indicators evidenced that technology transfer through rural extension did not improve the technological level for most farmers (Gómez-Oliver, 1995; Méndez, 1998; IICA-GTZ, 2000; De Souza Silva, 2001; Calva, 2004; Ardila, 2010; Trigo *et al.*, 2013; Rendón-Medel *et al.*, 2015; Amaro-Rosales and De Gortari-Rabiela, 2016b; Solleiro *et al.*, 2017). Several factors explain this scenario, including the complexity of these public extension services created in Mexico to contribute to the primary sector and boost rural development. Public policies were fruitless, most likely due to the rapid turnover of employees and extension planning, poor inter-institutional coordination, inefficient spending, and public solid resource dependency. These facts imply an intention to prioritize organizational performance over benefiting producers.

The “Programa Integral de Desarrollo Rural (PIDER)” coordinated the public policies on innovation and technology transfer during this last

decade in Mexico. PIDER was created in 2014 in the structural reform framework by SAGARPA, in alignment with the PND. The second aim of the PND, “Achieve a prosperous Mexico,” and the fourth aim, “Achieve an inclusive Mexico,” entailed reducing food insecurity. The PND related directly to the fifth objective of the “Programa Sectorial de Desarrollo Agropecuario, Pesquero y Alimentario 2013–2018.” The PND integrated 11 components, a few derived from previous programs, fomenting agricultural production since food production declined, leaving uncovered Mexico's demand (CONEVAL, 2015; Rendón-Medel *et al.*, 2015; Amaro-Rosales and De Gortari-Rabiela, 2016b). PIDER aimed to contribute to food insecurity reduction, focusing on extremely-poor populations in impoverished urban regions. The specific goal was to increment food production by mediating the acquisition of agricultural inputs, infrastructure (sustainable soil and water usage), and equipment. Also, PIDER's aims were: 1. to carry out comprehensive productive projects for development; 2. to capacitate and professionalize rural innovation and extension services; 3. to strengthen rural organizations; 4. to increase insurance schemes to attend to any potential loss caused by natural disasters. This new program derives from the “Programa Integral de Capacitación (PIC)” from 2013, as mentioned above. The PIC was one of the most recent efforts to reorganize agricultural extension services in Mexico while retaining previous programs' characteristics, such as the investment in innovation (CONEVAL, 2015; Rendón-Medel *et al.*, 2015; Amaro-Rosales and De Gortari-Rabiela, 2016b).

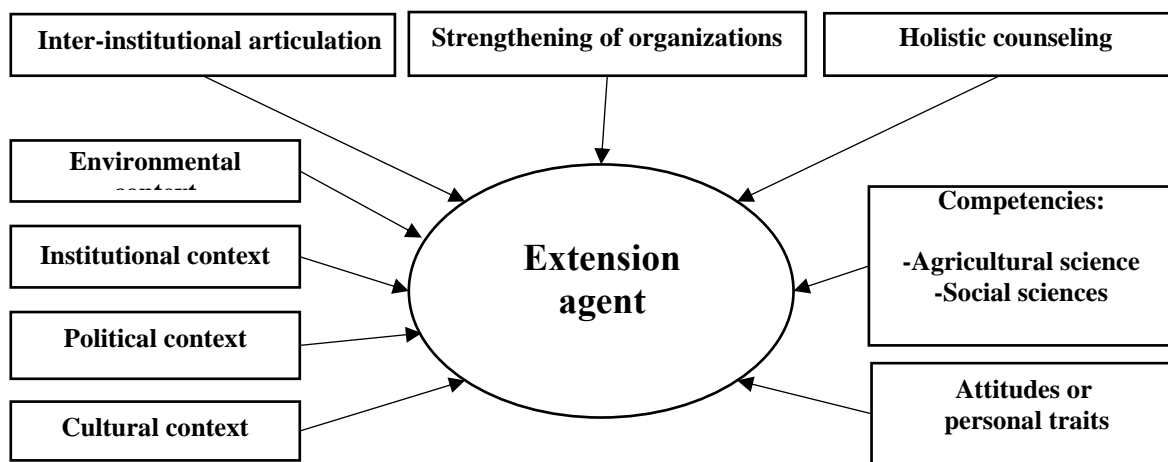


Figure 2. Factors that contribute to having a good extension agent. Figure adapted from Landini (2016).

WHAT MAKES A “GOOD EXTENSION AGENT”

Bensch and Peter (2015) mentioned the importance of evaluating the effectiveness of an intervention oriented by technology. These contemplated the incidence of technology adoption (the broad margin), following its future use: the intensive margin. Furthermore, some factors that can influence technology adoption are educational level, family income, communication skills, attitude, and gender (Hay and Pearce, 2014; Shah *et al.*, 2014). The impact of extension services on combating poverty and cooperatives' role in technology adoption is significantly more substantial for smallholders with access to credit than those who do not have access (Wossen *et al.*, 2017).

These facts reinforce the importance of rural extension services to hold agricultural practices and economic growth. Nonetheless, these services depend upon environmental, institutional, political, and cultural contexts. Furthermore, capacitating extension technicians in interpersonal abilities and social sciences is fundamental to reach the expected outcomes. Three areas in extension work are important: inter-institutional articulation, strengthening farmers' organizations, and providing holistic counseling service; in this sense, Cadena-Iñiguez *et al.* (2018b) also recommend generating a support platform to train, instruct and accompany, in addition to providing an evaluation to the extension agents themselves, to guarantee in the first instance the protection of the plant genetic resources of family farming. The rural extension has to go beyond productive and commercial support, so a good extension agent must be competent in both agricultural and social sciences to address the complexity of development processes. Furthermore, she/he must possess personal attitudes and abilities to work fruitfully, bond with people, listen, be sincere, trustworthy, humble, flexible, and committed to producers, among other traits (Figure 2).

CONCLUSION

As described above, Latin America and specifically Mexico developed social assistance and rural extension. Such policies remain innovative for Latin American countries, albeit with a considerable ongoing challenge for broad policy adoption and long-term policy delivery. Thus adopting technological innovation is a crucial element for economic development at the country level. Among the key actors for creating innovation

in Latin American agriculture, academia (universities and research institutes) remains the driving force. Research institutes have been created with clear innovation-driven objectives, although their goals varied due to economic and political pressures. Nevertheless, it became clear the need for synergy among academia and extension programs to observe the positive effects of technology transfer on the primary sector.

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