

Case Study on Agricultural Extension in Mexico as Part of the North American Agricultural Advisory Network Strategy

Extension and Farmer Support in a Multi-Faceted Environment

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Message from Secretary Victor Villalobos

"When we received the invitation from USDA Secretary, Tom Vilsack, and the System Chancellor of the Colorado State University, Dr. Tony Frank, to integrate the North America Agricultural Advisory Network, we were very enthusiastic to be part of an initiative that will strengthen the collaboration of Mexico with our closest trading partners, by closing the gap of our agricultural universities and Research Centers with Land Grant universities in the United States and the universities in the Provinces of Canada.

At first, we saw this as a challenge, nevertheless it was very much of an interest to us, given the fact on what our industries and rural areas in our three countries are currently facing: the aging of the rural population, the migration of young people, either to urban areas or to other countries, and the challenge to produce more for a rising population amid a never-seen climatic adverse environment.

We realized that Agricultural Extension Services and Technology Transfer and their role within agricultural production, food supply chain and rural development, are different and therefore in our perspective it was fundamental to understand the various elements involved in the North American regional ecosystems. This will facilitate, not only our understanding, but the exchange of experiences and a common adoption of best practices, technology transfer, and a better promotion and advocacy of agricultural advisory services in the region.

Extensionists must be at the core of the agrifood system and its constant transformation; and be also maintained as a solid and strong link in the food supply chain, so that innovations generated at the research level can be brought to farmers, ranchers, and fishermen, making food production more efficient, safe, reliable, sustainable, profitable and friendlier with the environment, while having the ability to respond to constant challenges and build resilience for future generations.

We are convinced that science and innovation are key elements to face the challenges on producing efficiently, sufficient, nutritious, safe and affordable food while facing a challenging climatic environment, and significant components to preserve our natural resources, manage our soil and water and protect our biodiversity for future generations.

Building synergies between research institutions, scientists and extensionists and advocating and promoting international cooperation is fundamental to achieve these goals.

Similarly, we must foster leadership building and strengthen the entrepreneurial spirit of young boys and girls, so they can, not only be active participants, but vocal in orienting the much-needed changes to transform them into sustainable agricultural and food systems.

We are very excited of the progress done at the North American Agricultural Advisory Network, and we believe that having the advice and experience of experts, such as Dr. Cathie Woteki, David Nielson, Doug Steele, Matthew McMahon, and Francisco Escobar Vega, among other will be instrumental in encouraging a dialogue to design efficient public policies for a sustainable agriculture, and be able to attract new generations to an active participation within this industry, as well as in productive activities in rural areas, bringing economic, environmental and social development in their respective communities.

We must allow and evoke the young to dream, to be inquisitive, and to foster and nurture their thriving spirit.

The country chapter studies on extension networks and agricultural advisory services in Canada, the United States and Mexico prepared by their respective country teams will also provide important elements and insights for discussion and proposal-building, and we certainly look forward to the next steps under this scope of cooperation.

We are convinced that this collaboration will be game changer to our research institutions, to many small-scale farmers, to indigenous communities, and to our youth from remote communities, by bringing a positive effect in the access to knowledge and science. NAAAN will help to make a difference, so they can definitely change their world.

Thank you very much."—Secretary Villalobos

1.1 Context and Scope

Because of its location, Mexico provides an entry point for agricultural trade for all of North America, in addition to its strong business ties with Central and South America and features tremendous culinary and cultural diversity. The country's stretched geography, rugged topology, and long coastlines along two oceans results in multitudinous microclimates, agroecologies, and crop production systems, most of which are found at tropical and subtropical latitudes. Accordingly, Mexican agriculture is rich but complex to systematize and improve, generating the need for in-depth multidisciplinary research and experts with an ample range of specialties, along with solid, flexible and interlinked exchange and knowledge transfer programs.

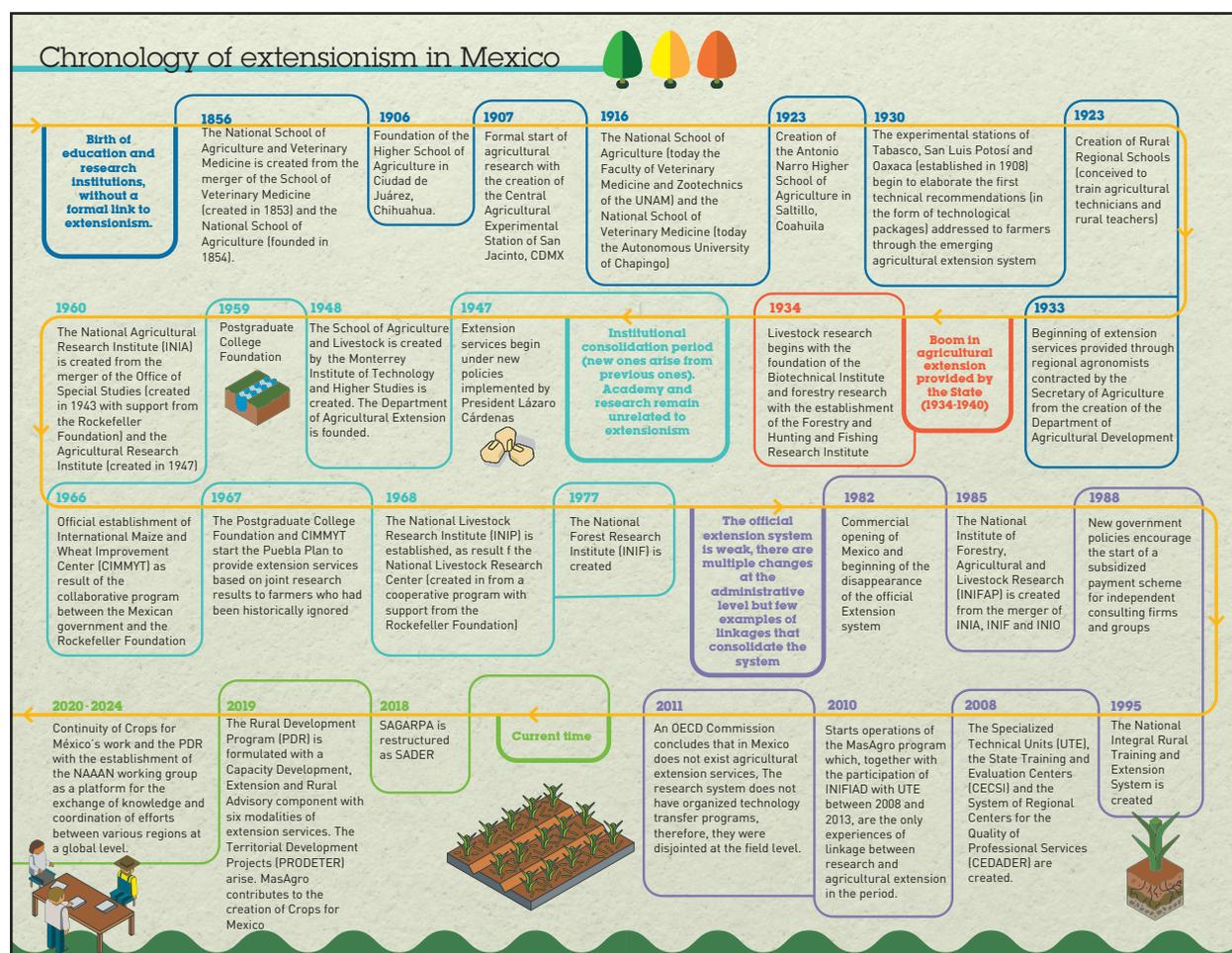
Mexico also struggles with severe socioeconomic challenges, starting with a highly-urbanized (80%) population concentrated in a few cities and dependent on food supplies from rural areas whose residents are ageing and rapidly diminishing (FAOSTAT, 2018). Mexico is the 11th ranked country in the world in terms of agricultural production, representing 3.7 % of its GDP (CEDRSSA, 2019), and with 21 million hectares of arable land it provides employment for nearly 7 million of its 130 million inhabitants (SIAP, 2019). Furthermore, although Mexico has improved its Human Development Index (currently with an HDI of 0.774), in 2018 42% of its population was impoverished and 1 in 5 Mexicans suffered from hunger (FAO, 2021), and in 2016 70% of the population was found to be overweight or obese (INSP, 2018). These data confirm Mexico's paradoxical situation (FAO, 2021) and explains the government's agri-food policy, which focuses on increasing overall well-being while attending to the needs of small- and intermediate-scale farmers (owning on average land less than 5 and 15 hectares, respectively), who represent 85% of the nation's farmers. Most of the latter

are only informally organized and many pursue subsistence agriculture, in contrast to the market orientation of Mexico's larger-scale and more politically influential farmers.

Although Mexico invests more public money in agriculture than any other Latin American country, in relation to its GDP, the lion's share of this budget consists of direct transfers to farmers as income support or farm input subsidies (Govaerts et al., 2019). The last decade the budget for agricultural extension has not exceeded 1.7% of the primary sector budget, with the highest amount during 2016–18, and representing an average annual value of USD 63.5 million. With such limited resources applied over such a large territory and facing significant socioeconomic adversity -including outmigration and organized crime in rural areas (Läderach et al., 2021), it is easy to understand the difficulties of establishing consolidated extension programs that produce sustainable and scalable long-term impacts. More so, according to the National Agricultural Census, only 1.3% of all rural productive units have access to farm assistance and training services, which is 15% fewer than in countries with a more developed agricultural sector.

To establish a systematized approach to agricultural extension in Mexico that pursues modernization within a reality of great disparity is a complex challenge. This document aims to provide an overview and history of Mexico's multi-faceted agricultural extension effort, as managed by the country's public sector and partners over the last century, with a graphical timeline given in Figure 1.

Figure 1
Graphic chronology of agricultural extension in Mexico



Source: CIMMYT/Mayra Servin.

1.2 Origin of Public Agricultural Extension in Mexico

Agricultural research in Mexico initiated formally in 1907 with the creation of the Central Farm Experimental Station in San Jacinto, in the Federal District about 30 miles outside of Mexico City and which was then the seat of the National School of Agriculture and Veterinary Medicine (Urbina Hinojosa, 2017). In 1908, three more experimental stations were established in the States of Tabasco, San Luis Potosí, and Oaxaca. During the 1930s, following the Mexican Revolution and the establishment of a stable national public administration, the main goal of the experimental stations was to generate technologies and elaborate recommendations in the form of “technological packages” for delivery to farmers through a nascent agricultural extension system. With this idea, throughout the twentieth century multiple national centers and institutes were established to build technical and research capacity, and with them the renowned National Autonomous University of Mexico (UNAM, hosting today the Faculty of Veterinary Medicine and Zootechnics), the Autonomous University of Chapingo (UaCH, an outgrowth of the National School of Agriculture) and the Superior School for Agriculture Antonio Narro (now Autonomous Agrarian University Antonio Narro, UAAAN). In 1985, Mexico launched the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), an integrated body of all research related to livestock and biotechnical topics, forestry, hunting, and fishing, and farmland studies (Cervantes Sánchez & Román de Carlos, n.d.; Terán y Terán, 2008; Universidad Autónoma Chapingo, n.d.; Urbina Hinojosa, 2017).

Additionally, given the vast natural biodiversity of maize, Mexico was destined to become a global center of excellence for this important staple crop (Damania, Valkoun, Willcox, & Qualset, 1998). In the case of wheat, the country’s agro-ecological diversity led to the creation of breeding schemes involving multiple cycles per year phenotyped at contrasting locations, known as “shuttle breeding” (Ortiz et al., 2007), which accelerated improvement and broadened wheat’s adaptation. Breeding research in Mexico for tropical maize, including the first widespread collection and cataloguing of related genetic resources, and to develop high-yielding and rust-resistant wheat, gained tremendous impetus under the joint Mexico-Rockefeller Foundation “Office of Special Studies” established in 1943 (Byerlee, 2016). The successes of that program led among other things to the launch in Mexico in 1966 of the International Maize and Wheat Improvement Center (CIMMYT), a 1970 Nobel Prize for wheat scientist Norman E. Borlaug, and the establishment of CGIAR, the leading, global agricultural research-for-development partnership. The Mexico-Rockefeller Foundation program also influenced the format and approaches of INIFAP’s predecessors, which included seeking international partnerships, particularly with US experts and organizations. Benefiting from Mexico’s genetic and ecological diversity and development experience, CIMMYT has generated and shared improved varieties of maize and wheat, as well as related genetic resources, knowledge, and improved cropping system practices to benefit farmers and consumers worldwide (Krishna et al., 2021; Lantican et al., 2016). Its presence in Mexico has helped offer responses to the changing local demands of agri-food systems and actors, as well as consolidating a strong relationship with Mexican farmers in co-development and co-learning for rural development (Camacho-Villa et al., 2016).

In line with Mexico’s Agricultural and Rural Development Sector Program (ARDSP) 2020-2024 (Secretaría de Agricultura y Desarrollo Rural, 2020), INIFAP contributes to the three, primary ARDSP objectives: 1) Achieve food self-sufficiency by increasing agricultural, livestock and aquaculture production and productivity; 2) Contribute to the well-being of the rural population by including historically excluded farmers in rural and coastal productive activities, taking advantage of the potential of the territories and local markets; and 3) Increase the use of sustainable production practices in the agricultural and aquaculture/fishing sector in the face of agro-climatic risk. The third objective favors innovation management and transfer using fourteen technology transfer models, of which seven are participatory models in a context of direct agricultural extension. At present INIFAP has developed technical support activities for the programs issued by

the Secretary of Agricultural and Rural Development, in the field of rural extension called PRODETER¹ (Spanish acronym for Projects of Localized Development) and within the Technical Support Strategy of the Well-being Production Program. For their implementation, INIFAP works in 30 Mexican states and 11 SADER-supported food production chains (maize, beans, rice, wheat or bread, chia, amaranth, sugarcane, coffee, cocoa, honey, and milk), offering technical support and technologies to farm advisors and farmers related to agriculture, livestock and forestry.

Several other Mexican research institutes and educational centers play essential roles for agricultural extension. Founded in 1959, the Postgraduate College (COLPOS) pursues teaching and research together with capacity building and technology transfer services for actors in the primary production sector and, especially, smallholder farmers, in accordance with ARDSP and its institutional program. Finally, the Centre for Biological Research of the Northeast (CIBNOR), established in 1957, generates scientific knowledge through research that responds to the needs of the agricultural sector, leveraging as well strong private sector relationships. CIBNOR operates mainly in the North, with its headquarters in La Paz, Baja California, and branch offices in Baja California Sur (Guerrero Negro), Sonora (Guaymas and Hermosillo), and Nayarit.

2.0 The Evolution of Agricultural Extension in Mexico—Divergence and Convergence

Although public agencies began conducting limited extension activities early in the 20th Century, formal agricultural extension services were launched in 1933, with the founding of the Department of Agricultural Development. From 1934 to 1940, agricultural extension boomed through President Lázaro Cárdenas del Río's support of land distribution to farmer organizations. According to Terán y Terán (2008), public extension services consolidated officially in 1947, building on Cárdenas policies and when the department of Agricultural Development renamed the Department of Agricultural Extension in 1948 (Reyes Osorio, 2013). At that time, the USA had been operating agricultural extension services through land-grant universities for several decades. Lacking a similar system, Mexico started an “extension experiment” by contracting regionally based agronomists through the Secretary of Agriculture (Terán y Terán, 2008). So, rather than being provided by universities, extension services are offered by the government. In Mexico, “extension” is understood as instruction, technical guidance and practice made available to farmers, while “technical advisory service” refers to an intervention at individual farmer level. Because the challenges faced by rural inhabitants in Mexico are not only agri-technological but also socio-economic, a new concept of “rural extension” emerged (Vázquez Alvarado, Solé Salgado, Gutiérrez, & Trinidad Ruiz, 2015), aiming at the informal education of rural populations and requiring multidisciplinary knowledge and practices that strengthen an integrating and motivational vision regarding tradition and where communication has much to contribute.

The present-day situation reflects administrative changes begun in 1982, with a new economic paradigm based on competitiveness, opening to external markets, and a new vision for development that included a heightened role for the private sector and, even, the privatization of parastatal enterprises and public services for agricultural. With this came a reorientation of extension toward productivity, in accordance with the demands of international markets and the elimination of longstanding trade barriers that had been fashioned to protect Mexican agriculture (Salcedo, 1999), as well as the removal of the official extension system. In 1988, government policies promoted the creation of enterprises and independent consultant groups under a subsidized payment scheme, where in some cases the accredited farmer was obliged to gradually absorb the cost of technical assistance (Salcedo, 1999). In other words, agricultural extension became a practice where sector professionals guided the knowledge transfer and productive processes for rural development.

¹ Of 420 PRODETER regions, INIFAP operates 128 directly and 110 in collaboration with state governments.

Thus, with a focus on developing practices and tools to increase productivity, extension in Mexico evolved during the second half of the 20th century towards a centralized model of accredited professional service providers paid with public resources. As a result, today there is no single extension model in Mexico, as signaled by the OECD in 2011 in the publication ‘Analysis of the Agriculture Extension in Mexico’ (McMahon & Valdés, 2011), but a multitude of schemes operated by independent entities (INIFAP, COLPOS, CIMMYT, CIBNOR, UaCH, among others) that offer technical assistance to farmers as part of distinct support programs of the Secretary of Agriculture and which depend on the context, budget and local demands and are aligned with federal policies. With the “Law of Sustainable Rural Development” passed in 2001 as regulatory law of Article 27 of the Mexican Constitution, the federal government continues to develop capacity building schemes for the rural population and their organizations to improve agriculture, foster sustainable rural development, and increase rural entrepreneurial skills. During this period a service fee was put in place for training, technical assistance and consulting to stimulate the emergence of a market for private extension in support of locally-oriented governmental programs. Because of this, in Mexico someone who carries out extension work for the government is called “an extensionist,” whereas those contracted by other actors are denoted “professional service providers” (Vázquez Alvarado et al., 2015).

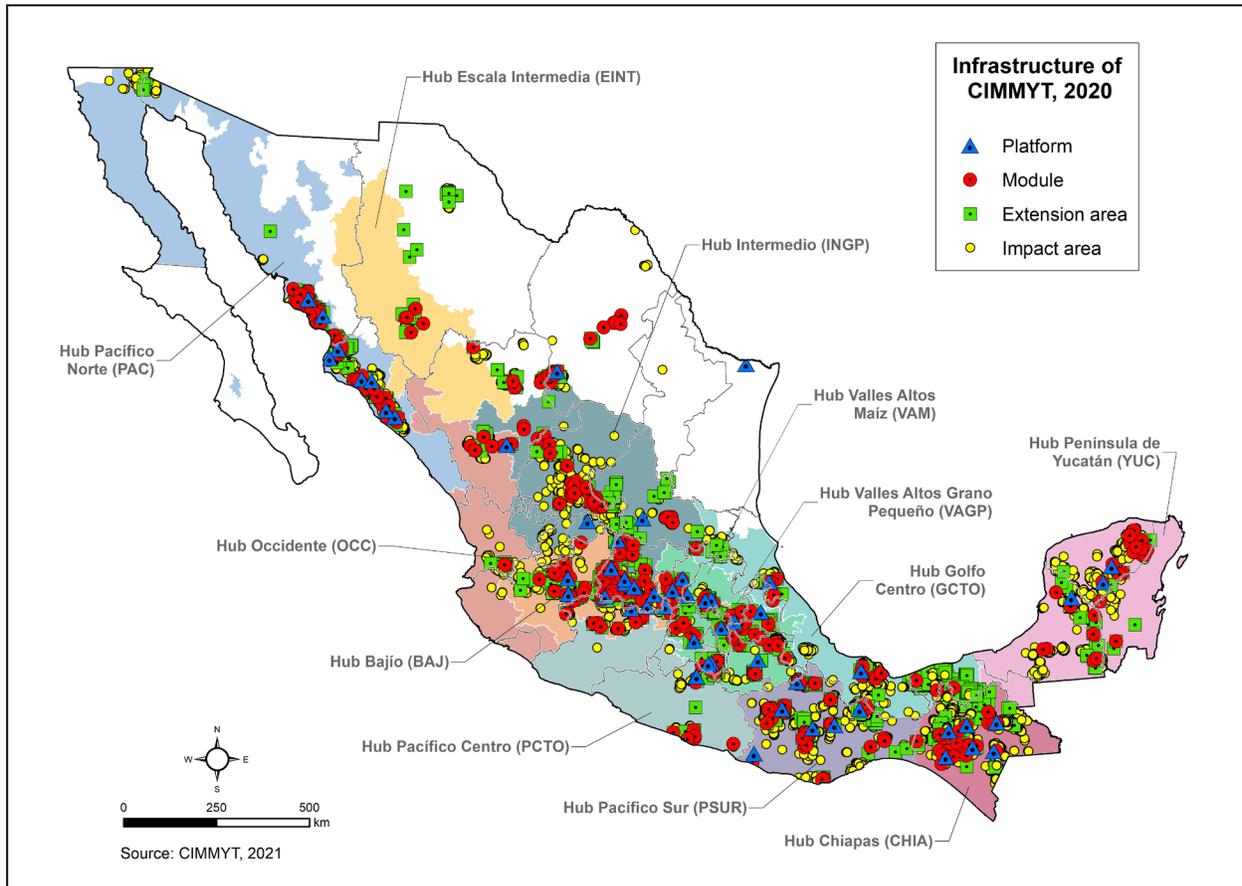
These institutional changes have generated a broad panorama of structures and elements to catalyze innovation under particular conditions and in specific settings, but lack the ability to generate feedback loops or systemic evaluations of quality and learnings to foster institutional interaction (Govaerts et al., 2019). Moreover, except for INIFAP’s Specialized Technical Units² (STU) for livestock services during 2008-12 and the STU for agricultural services during 2011-13, there has been no formal linkage between research and extension in Mexico. However, responding to this need and in view of its commitment to increase the productivity of maize and wheat crops, CIMMYT has developed a methodology that promotes collaboration among local actors through participatory schemes, with farmers as the main agents of change. The MasAgro initiative started in 2009 as a model based on design thinking, through which CIMMYT, as an independent broker, coordinates public-private partnerships involving INIFAP, state universities, and companies, among others, as well as integrating service providers by agroecology. The aim is to consolidate efforts attending to farmers’ needs, according to their scale of operation, production systems, technology level, and socioeconomic circumstances (Liedtka, Salzman, & Azer, 2017).

The model interprets agricultural extension as a technical mentoring in support of experimentation and adoption of good farming practices by leading farmers, researchers, and change agents. This operates through innovation nodes or hubs located in agroecological zones defined by crop (maize, wheat and associated crops) and farming system. Each hub features an infrastructure of learning spaces including research platforms, modules, and extension and impact areas that facilitate networking, knowledge exchange and co-creation (IICA, 2016). In research platforms, local scientific partners evaluate technologies and local knowledge to develop recommendations for farmers. In the modules, farmers are connected to peers, farm advisors and other value chain actors. Together they implement and adapt best practices from research platforms and compare them with conventional practices. Extension areas are fields where farmers test solutions in connection with modules or research platforms. Impact areas are where farmers have adapted and adopted similar innovations on their own. This network of stakeholders seeks to innovate and improve the sustainability of agri-food systems, through increased awareness, knowledge sharing, and the alignment of value chain actors (Gardeazabal et al., 2021). Each component of this infrastructure is built upon an agreement of collaboration and shared commitment in response to farmers’ needs.

² The Specialized Technical Units (STU) were created in 2008 under the guidance of the Under-secretariat of Rural Development, now the General Coordination of Rural Development, of the Secretary of Agriculture and Rural Development (SADER) to create a strategy for training, technical support, monitoring and evaluation of the subsidized professional services farmers receive.

Thus, through the hubs agricultural extension becomes a dynamic social process involving farmers, farm advisors (or professional service providers) and extensionists, researchers and their institutes, and companies, to exchange information and knowledge and increase innovation and productivity, without losing a local focus and ensuring feedback for quality control (Liedtka et al., 2017). CIMMYT operates 12 hubs covering 29 of 32 states, with 38 active experimental platforms connected to 308 modules and 790 extension areas in 2020 alone (Figure 2). From 2010 to 2020, farmers on more than 1.3 million hectares have adopted innovations transferred through the innovation nodes.

Figure 2
Infrastructure of CIMMYT's 12 innovation nodes or Hubs in Mexico for 2020



Source: CIMMYT (2021).

Simultaneously, INIFAP has promoted extension services provided by national institutes, building on more traditionally implemented participatory models. At present, through its 38 experiment stations throughout Mexico, technicians and farmers are trained in the use of technologies and related processes for agriculture, livestock and forestry. INIFAP shares its own science and that of others through the publication of agriculture, livestock and forestry journals, along with teaching materials based on the published findings, for use by farmers and technicians and more general distribution to the target audience; materials to support testing activities and backstop demonstration plots. Perhaps INIFAP's most successful and long-lived transfer model has been the Ranchers Groups for Validation and Technological Transfer (Spanish acronym, GGAVATT), focused on livestock ranchers and operating in all Mexican states up to 2018. It featured three key agricultural extension components: field research, technical support, and linking extension workers with farmers and ranchers. INIFAP's transfer models in support of technicians, extensionists, facilitators, and innovators have operated on diverse financing (national or international, public or private, or combinations of these), along

with state-level support to ensure continuity and distribution of money transfer to the farmers. The INIFAP models have been replicated abroad under bilateral agreements between Mexico and Belize, Brazil, Colombia, Nicaragua, and Paraguay.

As part of its distinct vision, CIBNOR promotes its staff's strategic agroindustry research as the basis of its extension-related activities and services. These have operated as of 2019 by way of its "Coordination of Linkages, Innovation and Knowledge Transfer to Society" programs (Spanish acronym, COVITECS) to generate and disseminate scientific knowledge and innovations and develop technology and human resources, addressing the needs of farmers, organizations, institutes, and companies at regional, national and international levels. CIBNOR's broad coverage owes partly to extensive partnerships with universities, public research institutes and government agencies, NGOs, and international organizations.

The more traditional agricultural extension strategy of COLPOS balances scientific research and the preparation of academically trained specialists with the field-based services of training and technology transfer towards farmers. The implementation of "Plan Puebla"³ in 1967 proved the effectiveness of combining scientific research with extension services and working directly with farmers and their families to promote innovations with demonstrated potential to increase productivity. Building on this nationally and internationally recognized experience, COLPOS has updated its strategy to extend capacity building and technology transfer to social groups in areas near its campuses and, especially, those considered highly marginalized, designated "Priority Care Microregions."

These approaches have converged as of 2018 under the guidance of the current federal administration and building on a national "diagnosis" by the Secretary of Agricultural and Rural Development to design a "Program for Rural Development," within the framework of the National Development Plan 2019–2024. The diagnosis included an extensive review of extension services and the capacity building requirements to address the needs of smallholder farmers and fishermen. The Program for Rural Development aims to sustainably increase the productivity and incomes of rural households, designated "Family Production Units," in highly marginalized locations including Priority Care Microregions (Diario Oficial de la Federación, 2018). The Program is implemented through the Secretary of Agricultural and Rural Development's 191 Rural Developments Districts and 713 Rural Development Support Centers in 32 states and in coordination with state-level governments. The Program also designated 420 PRODETER intervention areas in which since 2019 a five-year intervention is underway to achieve established goals established.

3.0 Capacity Building as a Requirement for the Continuity of Extension Work

3.1 Field Schools Under the Motto "Learning-by-doing"

A key part of the INIFAP agricultural extension models is the formation and training of technicians, farmers, and children of farmers through practical, learning-by-doing courses and seminars conducted in field schools. Work and demonstration modules allow technicians, farmers and other local actors to interact and facilitate adult learning, which are especially important considering that the average age in rural communities is 53 and many inhabitants are functionally illiterate or do not speak Spanish (technicians are often from the communities and speak the local languages). Targeted support tools include flyers and other print materials, along with audiovisuals and on-line resources (see, for example <http://clima.inifap.gob.mx/lnmysr>).

³ This work was done in collaboration with CIMMYT

3.2 Mutual Capacity Building Through Applied Research for Higher Education

Although COLPOS's activities on training and technology transfer are mainly for higher education and research, they also provide a feedback pathway regarding the relevance of academic work, helping to ensure that professors or research reflect reality in the field and remain updated on context-specific social and economic techniques. The institution's applied research takes place through seven campuses, but locally-imparted farmer courses can be highly relevant for a region and important for Mexican agriculture. Topics of interest have included small-scale agriculture and climate change, soil conservation and integrated water management, high-yielding crop varieties, postharvest storage practices, biotechnological innovations for disease control, livestock genetics and nutrition, organization of the farmer-production-marketing chain, and the need for sustainable, environmentally-friendly production (Tables 1 and 2).

Table 1
Number of training courses per COLPOS campus delivered to respond to the Priority Care Microregions (PCM)

Campus	Year					
	2015	2016	2017	2018	2019	2020
Campeche	23	0	36	35	18	44
Córdoba	54	148	130	15	58	31
Montecillo	32	79	15	37	22	0
Puebla	196	58	56	142	165	150
San Luis Potosí	21	5	5	4	12	8
Tabasco	20	8	5	6	3	3
Veracruz	35	28	86	32	24	10
TOTAL	381	326	333	271	302	236

Source: Personal Communication with Dr. Francisco Escobar Vega (www.colpos.mx).

Table 2
Main technology transfer activities and thematic for COLPOS, related to activities in the PCMs

Campus	Activities
Campeche	<ul style="list-style-type: none"> Management of high-density fruit trees Nursery production of forest species and use of GPS in the field Production of edible mushrooms in contribution to food security Biological crop control: Maize, Sugar Cane, Chihua pumpkin and cattle Business strategy for the production system: Chile habanero Tilapia farming in rural systems
Córdoba	<ul style="list-style-type: none"> Production and soil conservation Coffee roasting Integrated sheep management Beekeeping and meliponiculture Compost and vermicompost production Adding value to products from the beehive
Montecillo (State of Mexico)	<ul style="list-style-type: none"> Greenhouse flower production Mushroom production Production and commercialization of back-yard garden produce Dairy products and artisanal cheeses Industrialization of pig meat
Puebla	<ul style="list-style-type: none"> Demonstration modules for staple food crops Promotion of family and back-yard livestock production Agroecological management of fruit trees mixed with maize (MIAF) Pruning and orchard management (walnut, peach, hawthorn, etc.) Smallholder farmers organization

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San Luis	Use of Higuierilla for bio-energy and its by-products
Potosí	Participatory stratified mass selection of native maize for arid regions
Campus	Activities
Tabasco	Back-yard vegetable production module and poultry in subtropical regions In situ cocoa breeding Vermicompost and vegetable production Organo-ponic modules
Veracruz	Demonstration module for Malayan shrimp larvae production Demonstration module for edible mushroom production Hydroponics and soilless crops demonstration module Demonstration module for Moringa oleifera

Source: Personal Communication with Dr. Francisco Escobar Vega (www.colpos.mx).

3.3 Extension as an Integral Part of Scientific Research

The objectives of the different advisory, training and extension activities that are carried out for farmers by CIBNOR respond directly to its mission, vision and strategic objectives mentioned above and are reflected in its Academic Programs for Scientific Research (Table 3). All extension activities and services are aligned with the National Development Plan, as well as state- and municipality-level plans for food production.

Table 3

Research programs and strategi research lines for CIBNOR's intervention areas (La Paz, Baja California Sur and Northeast of Mexico)

Academic program for scientific research	Strategic research lines	Intervention area
Aquaculture program	Plankton biotechnology. Biology and development of techniques for the production of mollusks. Biology and development of techniques for the production of Crustaceans. Biology and development of techniques for fish production.	Guaymas
Dry zone agriculture program	Organic agriculture. Phytosanitary and food safety Agrotechnology and energy resources. Water, soil and climate for agriculture in arid regions. Biotechnology and the use of genetic resources.	Guerrero Negro
Fish ecology program	Effects of fishing in socio-environmental systems. Exploration, planning and sustainable development of new fisheries Variability and vulnerability of marine ecosystems. Maximizing the economic value of fishery products. Recovery, management and sustainability of new fisheries.	Guaymas
Environmental planning and conservation program	Ecosystem processes and environmental services. Oxidative stress. Coastal Systems and their environment. Biodiversity in Mexico: Problems, uses and conservations. Research for sustainable Development. Environmental microbiology Natural history museum: Taxonomy and systematization.	Hermosillo, Nayarit and Guaymas

Source: CIBNOR/Alejandra Nieto.

Most CIBNOR extension is an integral part of specific scientific research and transfer programs, so it is the investigators and technicians who conduct it and these people have become experts in their specialty. The academic profiles of most CIBNOR researchers includes postgraduate degrees (MSc and PhD), while farm technician profiles are more diverse. Researchers and technicians play complementary roles. The core vocation of CIBNOR is scientific research; extension is seen as complementary and a voluntary pursuit of researchers.

3.4 Extension to Mentor for Innovation and Human Capital Development

CIMMYT implements agricultural extension through a community-based approach and mentoring for innovation, seeking the long-term transfer of knowledge and fostering adoption of efficient practices for field-level innovation. This differs from traditional extension, in that it aims to consolidate and accelerate technical farm assistance supported by an enabling, knowledge management environment in which the farmer is co-proprietor and co-developer of innovative solutions. Key features include the following:

- Hub infrastructure is functional, dynamic and adaptable to different public policy programs for technical assistance and in accordance with the diverse needs of small-, intermediate-, and large-scale farmers.
- The direct, continuous and timely mentoring of farmers to co-develop and adapt innovations and encouraging farmer-to-farmer adoption for greater impact.
- Networks of collaborators-trainers constantly update their knowledge and skills for tutoring, monitoring, and evaluating farm advisors or technicians.

The development of human capital and the positive impact on rural social cohesion fulfills a strategic role in this framework and ensures that extensionists meet quality expectations, connecting science and technical expertise through farmer interactions. In this way, the innovation hub and network of collaborators-trainers offers pluralistic trainings as described in various studies (FAO, 2010; Missika, 2006; Otoo, Agapitova, & Behrens, 2009), able to focus simultaneously on the individual, organizations and the social setting, while giving equal priority to all three. The formation of individual leaders and change agents helps to develop stronger institutions; these institutions provide alternative norms and develop conducive environments for staff to develop those skills and, subsequently, individuals and institutions with a greater capacity to effect change (Gill, Jones, & Hammett, 2016).

As part of capacity building, CIMMYT pursues joint research with the National Agricultural Research Systems (SNIA) and involving national and international students from undergraduate and graduate degrees, to promote knowledge and a sense of vocation in present and future generations of scientists, while also offering training for agri-food system professionals and value chain actors, aiming to develop management and agronomic skillsets.

As part of the above, the Center conducts the “training-of-trainers” (ToT) and a “certified technician” program in sustainable agriculture. The ToT scheme connects theory with farmers’ traditional knowledge through in-person interactions and learning spaces in innovation hubs, constituting continuous learning for farm advisors and technical service providers and allowing them to make informed, creative relevant, and flexible decisions in diverse contexts and use their knowledge, ability and attitude responsibly. The certified technician course offers prospective or experienced farm advisors high-level, specialized training in sustainable agriculture, developing the technical and methodological knowhow to speed the spread of profitable, climate-smart farming tailored to local conditions. The course enables graduates to prioritize innovation, results, and accountability, following international guidelines such as those of the OECD (McMahon & Valdés, 2011) and standards of specialized research centers for technology transfer and agricultural innovation (Aguilar Ávila, Altamirano Cárdenas, & Rendón Medel, 2010). Regular interaction among trainers and

the expert assistance of certified technicians enriched through farmer feedback foster continual monitoring how improved practices and innovative technologies are applied throughout the crop cycle. Since 2009, CIMMYT has trained 449 certified technicians in 7 hubs and built a network of 24 trainers, all contributing to an average 400 field demonstrations and farmer training events annually, with a cumulative reach of over 300,000 participants.

In addition, through the federally funded support program “Technical Assistance to Beneficiaries of the PROAGRO Productivo Component,” MasAgro has provided technical mentorship to nearly 35,000 farmers working on more than 68,000 hectares, including personalized assistance with agronomic planning, in 16 Mexican states (Campeche, Chiapas, Estado de México, Guanajuato, Guerrero, Hidalgo, Jalisco, Michoacán, Oaxaca, Puebla, Querétaro, Quintana Roo, Tabasco, Tlaxcala, Veracruz, and Yucatán) during 2017–2018.

4.0 Attention to Farmers in a Changing, Multidisciplinary and Globalized Environment

4.1 Innovation Management Model for Competitiveness

Working with marginalized farmers in south-southeast Mexico, INIFAP aims to create innovation empowerment or appropriation among farmers by matching technology offerings with available natural and farmer resources, as well as providing training for agribusinesses, working through iterative improvement and building on the institute’s technology portfolio, as well as that of partners and farmers themselves. Technicians play a pivotal role to bridge farmers and research and therefore must be able to further the requisite interactions. Agribusiness training is critical to add value to produce and increase farm household income, particularly regarding the choice of products to grow/market and how to launch and run a business.

4.2 Specific Attention to Priority Regions

The work of COLPOS operating 14 PCM across agroecological zones has received special attention in recent years, with the UN and FAO emphasis on uplifting family farms and smallholder production systems to foster food security in developing nations. PCM activities in part aim to address decades of rural outmigration by working-age males in Mexico, with training and technology transfer targeted to women and older men who increasingly lead households and agriculture. Updates on this work are submitted regularly to a special government commission on the issue and feature in presidential reports.

4.3 Demand-Based Service Delivery

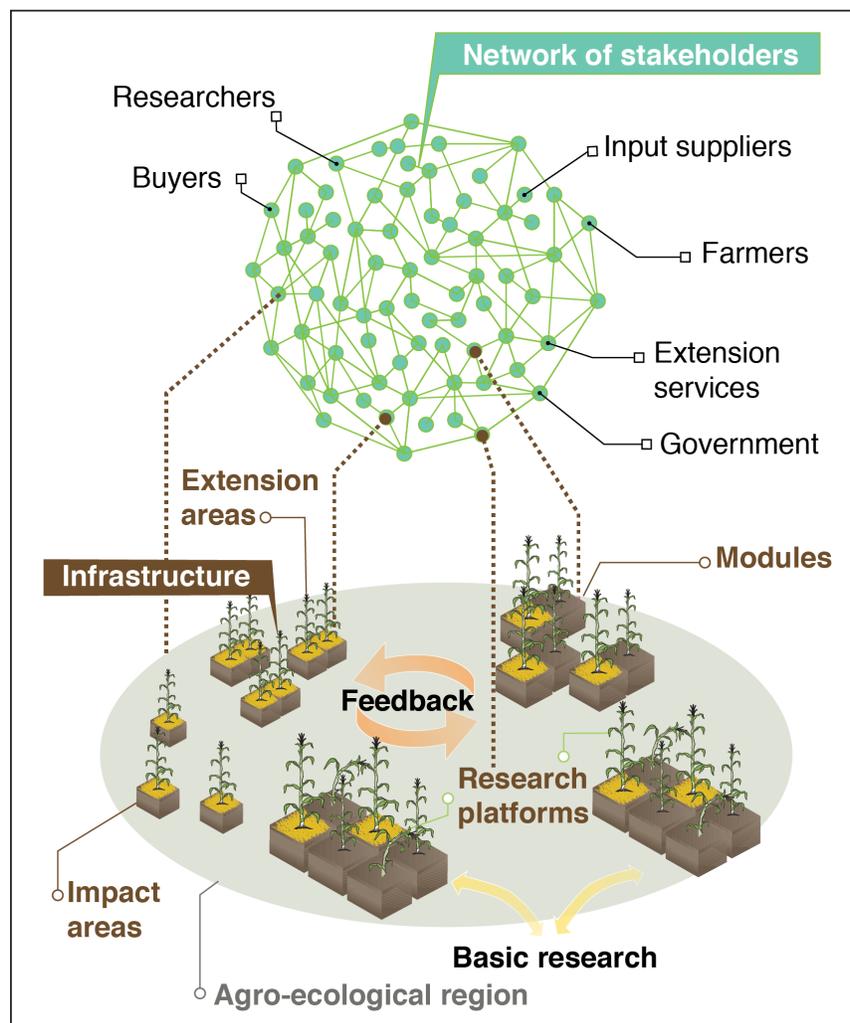
To attend to stakeholders’ extension needs, CIBNOR works to deliver on-demand services requested by farmers, public organizations or companies. COVITECS coordinate such requests based on perceived needs for innovation as articulated by their scientists and technicians, as well as students, entrepreneurs, and social and production sector actors. Such services may or may not be charged and can include courses and workshops, technical or scientific assistance, diagnostic services, lab and other analyses, transfer of biological materials, or knowledge or technology transfers. Services are usually provided through personal interaction or group events and digital and written materials, including technical manuals, educational brochures, and outreach materials.

4.4 Innovation Networks and Knowledge Management for Agri-Food System Innovation

MasAgro and its innovation mentoring model have established a network for effective communication regarding maize and wheat agri-food system innovation among farmers, independent practitioners and academics from national and international research communities (Figure 3), featuring diverse channels for social interaction and catalyzing cross-border knowledge flows and digital access (Gardeazabal et al., 2021; Govaerts et al., 2019).

Figure 3

Graphical representation of the innovation networks emerging from CIMMYT's HUB model (adapted from Gardeazabal et al., 2021)



Source: Gardeazabal et al. (2021).

The network is complex, with intensive, interrelated processes that require adaptive and integrative knowledge management and a high awareness of actors' priorities and relationships and of the linkages among technologies, practices and proposed solutions (Camacho-Villa et al., 2016; Schut et al., 2016). Its operation also requires an open attitude to support knowledge creators and disseminators, including local and regional intermediaries (Hellin & Camacho-Villa, 2017), as well as to facilitate feedback and overcome barriers to an holistic application of science, policy, and practice. The preceding is supported by a data capture system, as well as other digital science and communications technologies, to monitor progress, analyze outcomes and

generate recommendations at the field, landscape, country, and regional levels and within technical, commercial and political spheres (Gardeazabal et al., 2021).

For Mexico, CIMMYT has setup a monitoring and evaluation dashboard to capture learning and support accountability from field level data for up to 500 variables loaded by farmers, technicians and partners (CIMMYT, 2020). Data for activities from more than 200,000 fields have been registered, helping to hone agronomic recommendations and this is considered a frontier technology for agricultural extension (Analytics, 2020; SDNS & TRENDS, 2019). With such technologies, CIMMYT strives to strengthen knowledge management for innovation, improve the understanding of the complexity of agricultural extension in Mexico, and face the challenges of the country's diverse environment.

Government support of MasAgro helped to drive a paradigm shift in agricultural extension toward increased innovation based on an inclusive model of shared knowledge. A renewed commitment under the umbrella program "Crops for Mexico," led by CIMMYT and Mexico government through the Secretary of Agriculture and Rural Development, will replicate this model in multiple production systems and their value chains in order to broaden efforts to attract and leverage public-private co-investment to scale it Mexico-wide (Govaerts et al., 2019; IICA, 2016).

4.5 Extension Services Based on Strategic Planning and Participatory Diagnosis

From the federal government, the Program for Rural Development has started work in 420 PRODETERs with 100 extension workers specialized in strategic planning, to unite farmer groups of farmers and conduct participatory planning, identifying local problems and investment priorities for increased household productivity and income. In parallel, research and technology transfer activities are being led by competent institutions with local presence, experience, and technologies, including INIFAP, the National Fisheries Institute, COLPOS, UACH and several state universities.

Diagnostic and the planning exercises by locally-bound extensionists and farmers groups have defined relevant projects to strengthen primary production and economic integration, for implementation by 400 investment project development specialists. Best-fit extension profiles and technicians will be chosen for each project and value chain, the latter corresponding mainly to those that can ensure local food supplies in each PRODETER (e.g., maize, beans, milk, honey, coffee, fruit trees, meat and aquaculture-fish).

In the 420 PRODETERs, 2,600 extension workers from diverse agricultural, livestock, fishery and socio-economic disciplines have taken part in strategic planning, investment project development, and project operation, as requested and endorsed by farmers. These efforts have afforded support to more than 123,000 farmers in over 550 priority care and highly marginalized municipalities in 32 states.

5.0 Discussion: Extension in a Development Context

The national extension strategy reflects the aims of improving livelihoods and increasing food security in rural communities, by stabilizing basic food production and access to healthy diets (Swanson, 2008). Institutions such as INIFAP and CIMMYT reflect the national vision, helping to coordinate and integrate of multiple interventions and targets programs. The need to remain flexible to enable context-specific implementation and delivery is nonetheless clear, and this is where institutes like COLPOS and CIBNOR fit in.

Public-led extension for resource-poor farmers differs great from that targeting commercial scale farm enterprises (Swanson, 2008). Located in the North, where large commercial agri-businesses dominate farming, CIBNOR follows an outreach model tailored for private extension service providers. Export-oriented value chains, such as avocado, tomato and berries, generally receive no attention from public extension. Other

highly productive and commercially oriented value chains in the same region have often depended on farmer associations, in the absence of a privately organized extension services, and these have contributed significantly to Mexican research and extension.

Private-led extension in Mexico has focused on market demand, whereas public agricultural extension services have been linked to rural development goals and tackle issues such as food security and increased productivity, viewing “public goods” concerns such as social cohesion and natural resource management as of secondary importance.⁴ Notwithstanding, in recent years several federal initiatives of the Secretaries of Well-being and Education, with support from the Secretary of Agriculture and Rural Development, have also addressed the later.

Besides COLPOS, which has a strong research and extension arm, and several others⁵, universities do not play a significant role in technology transfer or even the formation of future professionals in this field. Mexican agrarian universities have no mandate for extension, mainly due to the scarcity of representative educational institutes in rural communities and the lack of finances.

Perhaps because of this, similar to the farmer associations’ support in the North filling the void of private-led extension, CIMMYT took on the role of linking its research for development capacity with extension in Mexico to scale innovations and strengthen agri-food innovation systems, given its close relationship and longstanding collaboration with Mexican policymakers and organizations. State governments also have a strong role in organizing and supporting extension services, as exemplified by the state of Guanajuato providing strong support for MasAgro and operating its own version of the MasAgro model since 2013.

An interesting question is if Mexico’s agro-ecological diversity accounts for the country’s varied state-level extension approaches or if it’s the national development context that results in a lack of coordination between state and federal governments?

6.0 Public Policies and Extension in the Agri-Food Sector

6.1 Areas of Opportunity and “Disruptive” Improvement

The ARDSP 2020–2024 mentions extension as a strategic policy instrument toward sustainable agriculture, aquaculture, and fisheries, encouraging in farming the efficient water and soil use and their long-term availability, as well as integrated disease and pest management, the conservation and recuperation of ecosystems services and the effective coaching of diverse farmers. Aims for the latter include changing farmers’ mindset and improving their skills, while acknowledging their culture and incorporating traditional know-how to preserve natural resources and stabilize or increase productivity.

In addition, to shake up the paradigm that extension should focus solely on production activities directly related to field operations and limited to the field itself, the idea of extension with a localized vision is proposed, recognizing the reciprocal connections of land use with the natural environment and landscapes. In fact, the natural resources and ecosystem services of landscapes are an integral part of agricultural, aquaculture and fisheries, so considering their availability and limits is one of extension’s great challenges.

From this perspective, agricultural extension must promote sustainable practices that maintain or increase productivity while conserving and integrating the biodiversity of its production systems. This approach will contribute to climate change adaptation strategies and farmers’ resilience by taking advantage of all available

⁴ With notable exceptions being the work of CONABIO (<https://www.gob.mx/conabio>) and CIMMYT’s effort for sustainable and climate-smart approaches

⁵ The universities of Chapingo and Chiapas are part of the Interinstitutional Groups for Extension presented in 2018 (Cadena-Iñiguez et al., 2018), while others, like the UAAAN, at present actively collaborate in the diverse rural development and agricultural extension projects.

practices, knowledge and technologies and shaping production according to farmers' local environmental and socioeconomic conditions. The main challenges for extension are to understand which tools and practices can be used for each production system and to ensure that each practice in the proposed menu of solutions has a sound scientific and evidence base and fits the socioeconomic context.

For this holistic vision to become reality, universities and the National Centers of Higher Education centers for agriculture must shape professionals able to address multidisciplinary challenges related to agroecologies, climate smart ecosystem management, and establishing competitive value chains in local and regional agri-food systems. Research centers should support the demand-based development of landscape-level alternatives through dialogue with farmers, considering traditional knowledge and share sustainable innovation with farmers and their communities.

Finally, agricultural extension "delivery" must be supported through effective communication and in a permanent dialogue with farmers, extension workers, technicians, researchers and governmental authorities. The channels established for this should enable continual (rather than occasional), open communication and motivate farmers to learn about innovations and incorporate new practices but holistically facilitate the integration of effective traditional know-how and techniques. Extension should also include youth and women in the extension work force and as part of the target population, considering the shifting demographics of rural communities and to stimulate generational renewal and the inclusion of women in the dialogue for productivity, if the way of life linked to primary production is to survive for those that choose to remain in the Mexican countryside.

6.2 Vision for Extension Services in the Framework of the 2020–2024 Sector Program

The Mexican countryside requires a continuous redesign of extension in line with arising challenges in the agricultural sector. Extension services can offer a solid avenue for improved smallholder productivity and incomes in poverty prone areas, but only when integrated and implemented in a coordinated manner, as described in the Program for Rural Development, avoiding unarticulated participation in the value chain participation that perpetuates the current, unequal distribution of income and wealth.

The new vision for national agriculture is one of food self-sufficiency, while safeguarding natural resources and growing food with a sustainable and inclusive focus, building on knowledge-based agriculture and capacity development through extension. Accomplishing this transition will require specialized extension service agents able to catalyze greater productivity in agriculture, aquaculture and fisheries, incorporating science and sharing know-how for innovative research, technical coaching, advisory services and capacity development. National markets and participants need to be strengthened through organization and association, the development of entrepreneurial skills, access to finance, functional local markets, and the promotion of common goods for rural distribution, supply, and consumption. Localized interventions based on strategic participatory planning will contribute to the well-being of rural populations through the inclusion of historically excluded farmers. Finally, the promotion of sustainable production practices through new knowledge-management, technology, and methodological models will help reduce farmers' agroclimatic risk.

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