Evolution of the knowledge system for agricultural development in the Yaqui Valley, Sonora, Mexico

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Knowledge systems—networks of linked actors, organizations, and objects that perform a number of knowledge-related functions that link knowledge and know how with action—have played a key role in fostering agricultural development over the last 50 years. We examine the evolution of the knowledge system of the Yaqui Valley, Mexico, a region often described as the home of the green revolution for wheat, tracing changes in the functions of critical knowledge system participants, information flows, and research priorities. Most of the knowledge system's key players have been in place for many decades, although their roles have changed in response to exogenous and endogenous shocks and trends (e.g., drought, policy shifts, and price trends). The system has been agile and able to respond to challenges, in part because of the diversity of players (evolving roles of actors spanning research–decision maker boundaries) and also because of the strong and consistent role of innovative farmers. Although the agricultural research agenda in the Valley is primarily controlled from within the agricultural sector, outside voices have become an important influence in broadening development- and production-oriented perspectives to sustainability perspectives.

environmental sustainability | technology adoption | fertilizer and water management

Over the last 50 years, agricultural communities in developing countries have experienced dramatic changes in their requirements for and access to information, knowledge, and know how related to cropping systems and commodity markets (1). As part of a post-World War II effort to enhance agricultural production, research systems focused on development and deployment of improved genetic materials and management practices for key food staple crops (2, 3). Over time, with the changing landscape of agricultural production (4, 5), transformations in global food demand and marketing systems (6), and increasing foci on sustainability objectives, including environmental concerns, these systems have been required to evolve to continue providing relevant support.

In this paper, we explore the evolution of knowledge systems for agricultural development that has occurred in the home of the green revolution for wheat. Knowledge systems are networks of linked actors, organizations, and objects that perform a number of knowledge-related functions that link knowledge and know how with action (including research, innovation, development, demonstration, deployment, and adoption).* They include the institutions, human capital, financial resources, and incentives that give such systems the capacity to function. Although knowledge systems are not the result of master design, they can be understood and manipulated in ways that improve their performance. Previous research has highlighted communication and translation among players within knowledge systems as key functions for managing the boundaries between scientific knowledge and decision making (7–9). To date, little attention has been paid to how these functions change over time in response to new challenges. We use examples from the Yaqui Valley (YV) in Sonora, Mexico, to examine the current state of the knowledge systems for agricultural development and their evolution in response to postgreen revolution agricultural sustainability challenges.

Knowledge Systems of the YV

As a leader in technology adoption and harbinger of change for northern Mexico, the YV is well-suited for a study on knowledge systems. It is home to a key research station of the Centro Internacional de Mejoramiento de Maiz y Trigo [International Maize and Wheat Research Center (CIMMYT)], one of the main centers of the Consultative Group on International Agricultural Research (CGIAR) system, and it was one of the earliest focal areas for developing country agricultural research and development. Involved in participatory research with agronomists, economists, and breeders, Yaqui farmers and farmer groups helped develop germplasm and management practices that led to dramatic increases in wheat yields. International, national, and producer efforts have all contributed to productivity gains in this intensively cultivated, irrigated valley, which is 233,000 ha in size.

Like many other postgreen revolution agricultural regions around the world, the YV has struggled to address the offsite impacts of heavy fertilizer use (10–12), the growing competition for water from other sectors (13, 14), and economic and policy conditions that undermine farm profitability (15, 16). Such transitions have put new pressures on the YV knowledge system to create and apply different kinds of information at the local level, because support for agricultural extension and research has waned (*SI Text* has a more complete description of the site and its challenges). The knowledge system has grown and evolved in response, although considerable challenges remain.

Using primary information collected through key informant interviews and farmer surveys and secondary literatures and descriptions, we trace the links between knowledge and action that allow the knowledge system to address the critical sustainability challenges that have emerged in recent decades. In-depth interviews with over 60 individuals from the organizations that comprise the YV knowledge system (including many farmers) are used to map its structure and dynamics. We analyze trends in farm management (e.g., cropping patterns and planting systems,

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input use, and marketing) using farm survey data collected by CIMMYT in the 1980s and 1990s (17, 18) and Stanford University in 1994/1995, 1995/1996, 2003/2004, and 2004/2005 (19).

Players in the Knowledge System

The YV knowledge system integrates scientific knowledge with experiential knowledge built through decades of agricultural tradition. It has influenced creation, adaptation, and use of knowledge to address challenges facing the agricultural sector. Fig. 1 depicts a 2005 snapshot of the YV knowledge system—its organizations, their multiple interactions within and outside of the Valley, and the multidirectional flows of knowledge between them. Its structure lends insight into which issues garner attention and research effort.

Many of the YV's agricultural research institutions were conceived alongside the green revolution to support development and delivery of agricultural inputs, services, and knowledge to farmers. CIMMYT releases improved germplasm (higher yielding and stress tolerant) into the National Agricultural Research System (NARS). The National Forestry, Agriculture, and Livestock Research Institute (INIFAP) and its subnational affiliates focus on adaptive breeding and management recommendations, with core budget support from the Mexican government. Recently, supplemental project funding from Mexican and international sources has replaced declining core budget support (20). Farmers have shaped research priorities through their local research and development funding arm, the Agricultural Research and Experimentation Board of the State of Sonora (PIEAES; known locally as the Patronato), which represents all farmers in the state of Sonora on agricultural research issues and supports agricultural research and development with funds raised from farmers through planting fees. The Patronato's success led to nationwide replication. In many cases, the most effective and relevant organizations rely on dynamic individuals who make critical linkages between knowledge producers and users.

A decline in government support for agricultural development from the late 1980s led to downscaling and decentralization of federally financed agricultural extension. According to practitioners and scientists, this resulted in a marked decline in official linkages between researchers and farmers. Extension service delivery was subcontracted to private sector providers, and fees were introduced for farmers who could afford the services (21). Technical advisors used by the YV's credit unions have assumed many of the state's extension functions. According to interviews, credit union technical advice is dictated by the revenue-maximizing interests of farmers and credit unions; a mechanism no longer exists for supplying extension services motivated by other objectives, such as reducing agriculture's offsite impacts.

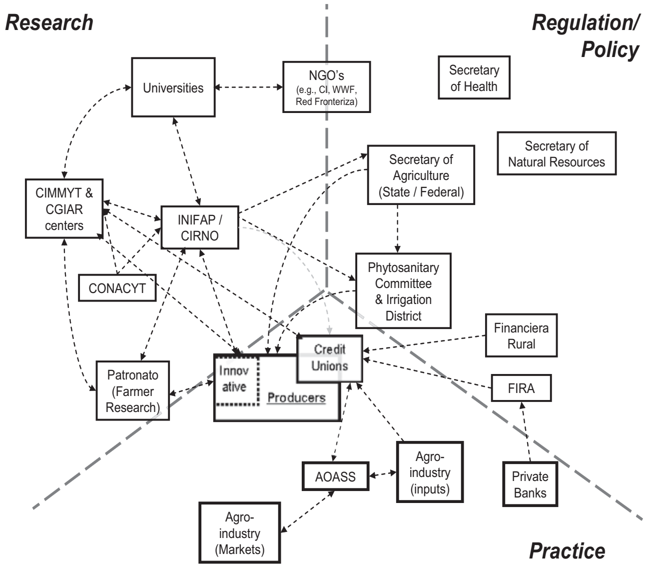

Fig. 1. Agricultural knowledge system in the YV between 1995 and 2005. Although many organizations exist, we describe the most influential ones in this work.

Most of the YV's farmers are organized in credit unions—farmer associations that provide members with credit, seeds, fertilizer, other inputs, insurance, postharvest storage, marketing, and technical assistance (Table 1). Membership rules require farmers to operate a relatively large land area (100 ha minimum). Although a few credit unions and similarly conceived public organizations cater specifically to smallholders and farmers from the ejidal sector, our interviews suggest that they typically offer fewer services and do not link strongly with the YV agricultural research and development institutions. Credit unions play a key role in scaling adoption of new technologies that research organizations have developed and farmers have tested. They form management recommendations from agronomic research, market information, and agribusiness outreach materials, and they require compliance for farmers to be eligible for the crop insurance services that they provide (according to interviews with credit union managers). Farmers claim that they adhere to the official recommendations[†] to receive services from the credit unions.

Two local organizations, operating under government charters with funding through planting fees, influence farmers' irrigation and pest management practices. These organizations are the Yaqui River Irrigation District, which oversees maintenance of irrigation infrastructure and allocation of water to groups of farmers [in conjunction with Mexico's National Water Commission (CNA)], and the Local Phytosanitary Committee, which guides pest management strategies in the YV. Agricultural producers are the centerpiece of the knowledge system. Farmers report in surveys that they draw heavily on their own personal experiences as well as those of their family, friends, and neighbors for information to support field management decisions, including fertilizer application (19). They also report relying on agriculture-related programming found in local newspapers and on the radio.

Given the importance of informal knowledge networks, leading innovative farmers play an important role. These self-described innovative producers typically have relevant university or postgraduate training in agricultural sciences and are regarded as influential decision makers. They often collaborate with researchers from national and international organizations to develop and test new management practices. They often hold influential roles in or relationships with credit unions, research funding agencies, and other institutions. Innovative producers form a critical link between researchers and the farming community by validating new technologies, assessing their economic profitability, and articulating farmers' needs and priorities to researchers (according to key informant interviews).

In the YV, science and technology are harnessed for improved field and farm management not through a one-directional pipeline between researchers and farmers but through a collaborative process by which farmers guide researchers' focus and validate new technologies. Farmer testing and validation is critical to eventual adoption of new technologies. Producers typically are motivated to enter into trials for technologies aiming to raise or stabilize their yields or lower their production costs; trials of management strategies to decrease off-farm impacts are not pri-

[†]Additional information regarding structured interviews with key informants, including credit union managers, is available upon request. Please contact the authors directly.

Table 1. Characteristics and services provided by the Yaqui Valley's major credit unions

	Grupo Yaqui	Grupo Cajeme	Ucayvisa	Grupo Copricom	Union Tres Valles	Alianza Campesino Noroeste
Number of members	840	400	100	1,012	146	2,750
Area cultivated	30,000	28,000	12,000	6,200	1,000	15,000
Sector (private or ejido)	Private	Private	Private	Both	Both	Ejido
Credit union	Yes	Yes	Yes	Yes	Yes	Yes
Insurance	Yes	Yes	Yes	Yes	Yes	Yes
Inputs and seeds	Yes	Yes	Yes	Yes		Yes
Marketing	Yes	Yes	Yes	Yes		Yes
Storage and milling	Yes	Yes				Yes
Processing	Yes					

oritized, although such outcomes may be valued as ancillary benefits. Innovative producers assume the risks of crop failure on plots planted to research trials, although they are affiliated with credit unions (according to farmer surveys and key informant interviews). These producers provide credit unions access to key data points around new technologies, which allow credit unions to understand them and pave the way for their eventual incorporation into mainstream management recommendations.

Results

The knowledge system shows varying effectiveness at fostering improved decision making in the face of typical green revolution and postgreen revolution challenges: transfer of new crop varieties, planting system innovations, fertilizer and water management, and crop diversification.

Transfer of Germplasm. The green revolution is most often associated with deployment of improved germplasm along with the packet of inputs and management information accompanying new varieties. The YV breeding system has been effective in reaching farmers with new wheat varieties. The Mexican National Agricultural Research System (NARS) institutions develop CIMMYT lines that are promising for Mexican farmers, and the Patronato (the farmer-funded research foundation that supports agricultural research and development, especially related to germplasm) receives breeder-quality lines from the local NARS station and sells them to credit unions, which multiply them and sell certified seeds to farmers. This wheat germplasm improvement system is consistent with CIMMYT's global model, although YV farmers benefit from particular proximity to CIMMYT's key research station and the regional NARS headquarters.

YV farmers often begin to adopt new wheat varieties almost as soon as they are released by CIMMYT (15), which is illustrated by a recent durum wheat leaf rust outbreak. In early 2001, scientists detected durum wheat leaf rust in the YV. CIMMYT and NARS researchers immediately used resistant races from their seed bank to develop, multiply, and release a high-yielding, advanced, rust-resistant line, which was broadly adopted by YV farmers within 2 y of the outbreak (22).

Planting Systems. During the 1980s and 1990s, most YV wheat farmers shifted from flat bed to raised bed planting systems. Raised beds have been used in high moisture systems to improve soil drainage for millennia, but the YV was the first semiarid, irrigated region to scale up adoption of the planting system (23). After successful NARS trials that were replicated at a local university in the early 1980s, innovative producers in the YV began to test the raised bed system in collaboration with national and international researchers. They found that it allowed for more efficient irrigation at lower effort than the flat field alternative while facilitating lower planting density, more effective weeding, higher yields, and more efficient fertilizer uptake (24). It required only minor adjustments to existing machinery. In surveys, farmers attributed their adoption to improved water management, better weed control, and easier field access with machinery (17).

Early innovative adopters improved yields while lowering production costs, and the technology soon spread to relatives, neighbors, and friends. By 1991, over 50% of farmers in the Valley had adopted the raised bed system (17, 19). Mostly members of credit unions, the adopters were spurred by credit union endorsement of the raised bed system. Smallholders from the ejidal sector were the last to adopt the technology, although by 2004, it was being used by over 90% of YV farmers (19). Agronomists have visited the Valley from all over the world to participate in CIMMYT's intensive raised bed training program, carrying their understanding back to farmers as far as Central, South, and East Asia.[‡] Innovative producers are key to spanning the boundary between agronomic research and adoption of improved farming practices, such as the raised bed planting system.

Fertilizer Management. During the green revolution, the Mexican federal government began to subsidize fertilizer production to keep domestic fertilizer prices below international prices (15). These economic incentives, along with extension recommendations that encouraged heavy rates of fertilizer application, resulted in a continuous increase in fertilizer use intensity from the 1960s to an average rate of 250 kg/ha (15). Approximately 75% of the fertilizer applied to wheat crops each year is typically applied 1 mo before planting, a practice linked with large losses of fertilizer from fields to the atmosphere and watersheds and associated economic losses for farmers (10). High levels of nitrogen in streams and canals draining the valley have been associated with greenhouse gas emissions (25, 26), and phytoplankton blooms in the Gulf of California have been linked with fertilizer losses occurring during major irrigation events in the YV (11, 27).

Starting in the late 1990s, researchers and farmers became more interested in increasing fertilizer use efficiency because of a growing awareness of the magnitude of fertilizer losses and associated environmental impacts, the scaling back of fertilizer subsidization and public extension, currency exchange rates that raised the local prices of fertilizer, and a sustained decline in global wheat prices (15). Surveys in the late 1990s indicated that fertilization was the single most important cost component in YV farm budgets, suggesting an economic motivation for using it more efficiently (10). Stanford University and CIMMYT researchers, with funding from federal funding agencies and foundations interested in sustainable agricultural development, evaluated alternative fertilizer management strategies that decreased the total N applied and timed applications more closely with plant uptake. All of the alternatives resulted in some reduction in N losses, and the best alternative, which called for

‡These planting systems lend themselves well to low-till management, which is now the subject of ongoing CIMMYT research in the YV.

25% less N per ha to be applied during and after planting, resulted in dramatically lower losses of N. Without differing in yields or grain quality, the best practice corresponded with estimated cost savings to farmers equivalent to 12–17% of after tax profits (10).

Next, the research team tested the apparent win–win practices in farmer fields, collaborating with innovative producers. Despite successful on-farm trials and farmer workshops to share the new approach, surveys indicated that application rates did not decrease (28). Inquiries into fertilizer application decisions revealed that lack of adoption of the new management approaches was likely because of uncertainty about soil and climate conditions by both farmers and credit unions (29), especially related to the risks of insufficient rates and late timing of fertilizer applications for optimal crop response (30). Credit unions continued to advise farmers to use the low-risk, time-tested management practices rather than adopt the new best practice (according to interviews with credit union managers). Their technical officers claimed that this advice was based on concerns about loan recuperation should crops fail. Because credit unions also serve as retailers of fertilizer, seeds, and other inputs, they had some financial incentive to maintain input sales volumes.

An approach to addressing farmers' production tradeoffs in adopting improved fertilizer practices has been to improve soil and climate information to allow farmers to better synchronize fertilization rates and timing with plant demand. This could simultaneously increase profitability while decreasing nitrogen pollution in adjacent air and water systems.[§] CIMMYT agronomist Ivan Ortiz-Monasterio developed an in-field nitrogen diagnostic tool to provide farmers with real-time soil nitrogen information. This sensor-based tool allows farmers to monitor nitrogen and add more if needed, and therefore, they avoid over fertilizing in most years without foregoing their full yield potential in optimal climate years. After calibrating the sensor in experimental plots, Ortiz-Monasterio began trials with innovative producers and then approached the Patronato, which engaged credit unions in the trials. Credit unions agreed to fund one-half of the costs of eight sensors, and Fundacion Produce Sonora funded a proposal for the other one-half of the cost. By engaging the credit union technical units, the researchers brought the toughest critics on board from the beginning, allowing them to reach a much broader audience of mainstream farmers (28). The sensor technology is now widely used in the YV, and it is spreading into other areas of Mexico and Asia.

Crop Diversification. Since the Valley's inception as a green revolution site in the 1950s and 1960s, wheat has dominated the cropping system thanks to favorable biophysical conditions for its cultivation, locally developed breeding innovations, and a generous, reliable endowment of surface irrigation water. Cotton, soybeans, and maize have all, successively, played important roles during the spring–summer crop cycle, which has been left largely vacant since 2002 because of drought. In recent years, the decades-long trend of declining wheat prices, rising production costs, and concerns about freshwater availability have threatened wheat-dominated agriculture. State and federal policymakers, along with progressive farmers, have begun to explore and promote crop diversification as a strategy for stimulating renewed growth in the YV's economy while using water more productively (according to key informant interviews held during 2003 and 2004).

Knowledge and information (related to production and marketing) are central to diversification, although it has been unclear that the YV knowledge system, focused for so long on a single commodity, could evolve to support the knowledge needs. Only 33% of YV farmers have ever expanded their cropping portfolios beyond basic grains into fruits, vegetables, or potatoes (19). Our surveys and interviews show that, for YV farmers, agricultural diversification is indeed knowledge-limited but not on the production side. Farmers claim that, rather than lack of production know how, uncertainties in market opportunities and high production costs prevent them from diversifying. Information barriers to developing marketing opportunities and negotiating favorable terms of sale can be formidable, especially for high value, highly perishable products whose markets are characterized by their high transaction costs, exacting quality and safety standards, and resulting production and marketing risks (31).

YV knowledge institutions are not currently poised to provide the market information and logistics support that can enable crop diversification. Interventions are needed to lower transaction costs through development of business capacity, support for forward contracting, and facilitation of marketing opportunities. For example, producer associations could negotiate contracts with buyers, coordinate supply logistics, and provide credit, technical assistance, and market information. The question remains whether the green revolution-initiated, wheat-focused knowledge system can evolve to meet these needs.

Water Management. The YV's heavy reliance on irrigation water is perhaps its most defining characteristic. A major drought in late 1990s and early 2000s was a sobering reminder of the importance of effective water management decision making and productive water use. During the 1990s, water resource management was decentralized from the National Water Commission to water user associations (32). The Yaqui River irrigation district was one of the first in Mexico to be transferred to users because of its reputation for promoting productive agriculture. In 1992, the district took responsibility for operation and maintenance of irrigation canals and infrastructure as well as a number of deep wells in the Valley (13). The National Water Commission (CNA) continues to operate the Yaqui River reservoirs and negotiates with the Irrigation District to allocate reservoir water to crop irrigation at the start of each year's wheat growing season (33).

After decentralization of water management, a long string of dry years led the Irrigation District to make a series of high-risk reservoir allocation decisions based on increasingly optimistic expectations of future in-season runoff (34). In 2002 and 2003, after 6 dry y and with reservoirs at precariously low levels, the Irrigation District authorized the sale of planting permits for an area that was 40% larger than it should have. According to long-term climate data, there was only a 50% chance that there would be enough reservoir inflows in season to allow the district to supply water to the fields whose planting it had authorized (34). The inflows did not occur, and the Irrigation District scrambled to procure equipment to pump water out of the main reservoir's dead storage capacity to deliver on the planting permits that it had sold the farmers. The district entered the following growing season with empty reservoirs. That year, the aggregate value of the YV's agricultural output plummeted to M$383 million, less than 40% of the average output value during the preceding decade in real terms (35).

After the YV's drought crisis illustrated to local water managers the consequences of their optimistic allocation decisions, the Irrigation District has begun to adopt a more conservative approach to water management (36). The District worked with scientists at the National Water Commission, Stanford University, and elsewhere to develop a water management strategy with risk-based operating rules that accounted for inflow uncertainty (33). A modeling and stakeholder deliberation effort culminated in adoption by Mexico's National Water Commission and the YV's

[§] It is difficult to obtain good information about weather patterns months in advance or about soil nutrient availability in real time. Work began on using El Nino Southern Oscillation (ENSO) predictions and other weather forecasting to provide information on seasonal weather patterns, but most efforts were focused on soil resources.

irrigation managers of surface water allocation rules that were designed to maintain minimum reservoir outflow levels through extended periods of variable and unknown inflows (14, 37).

Because farms comprise the largest source of demand for water in the YV, improved water management at the farm level will be important. As with fertilizer, powerful incentives provided by the credit unions and the Irrigation District's planting permit system enforce farmers' water use levels (35). Raising the price of water alone is unlikely to change practices. Even after the drought in 2003–2004, when the volumetric price of water doubled, irrigation records confirm that farmers who received water applied the same volumes as they did when it cost one-half as much (35). With improved data on crop and yield responses to different irrigation management practices and buy-in from credit unions, it might be possible to reduce the Irrigation District's allocation volumes or provide other incentives for more productive farm-level irrigation practices.

Discussion

The YV is subject to its own combination of organizations and individuals who face place-specific challenges that change over time. Although we cannot generalize observations about liking knowledge to action based on case studies of several agricultural management trends in just one location, we can learn from them. Here, we offer observations about the players in the knowledge system, information flows between them, and agenda setting. Our analysis highlights the dynamic nature of knowledge systems and the need for adaptation. When decision making rapidly devolved from federal and state actors to local ones in the 1990s and 2000s, the knowledge system simultaneously struggled to respond to key shocks that arose. As players reacted to the challenges that they faced, some roles and linkages within the knowledge system were strengthened.

Credit unions have expanded their roles to address more and more of their members' needs, because public support for agriculture was scaled back. They fill gaps, foster connections, and serve as central nodes in the knowledge system. The Yaqui River Irrigation District sought new links with scientists to address knowledge gaps made apparent during the drought. Over time, researchers' perspectives were shaped by their interactions with farmers. Researchers' close ties with innovative producers improved their ability to influence farmers' practices. Because the knowledge system included a diverse range of actors serving many different functions, it had the capacity to evolve and address postgreen revolution challenges. New concerns, including agricultural diversification, will continue to test the system in new ways.

The flow of information—its communication and translation across perspectives and between players—was key to the workings of this system (8). The Yaqui case negates the simplistic view of the one-way flow of scientific information from the agricultural research community to the user community. Instead, considerable multiway discussions motivate scientific endeavor, with the research community providing improved approaches (sometimes motivated by concerns other than those of the user community) while perceiving and responding to the needs and challenges faced by users. Close, iterative interactions between users and researchers seem to improve the effectiveness of the system.

Others have documented the importance of managing boundaries between scientific knowledge and decision making, whether through formal organizations designed to act as intermediaries between researchers and users or through individuals who assume that role (7–9). The YV examples illustrate the importance of venues that foster exchange of information between researchers, farmers, and institutions that influence their management decisions. State-funded agricultural extension systems are a classic example of organizations that link academic researchers and agricultural decision makers (8). When national reforms led to scaling back of extension in the YV, credit unions began to take on these functions. Their trusted role and financial relationship with farmers allowed them to become an important conduit for agronomic and market information. As influential leaders in these unions, innovative farmers then linked credit unions with the research community. However, unlike a state-funded agricultural extension system, credit unions lack a formal mandate to link to the research community, which has limited the exchange between farmers and researchers. The nature of credit unions' financial stake in farmers' management strategies also limited the types of their interactions with the research community to the exclusion of pursuing innovations that could improve the environmental and economic sustainability of farmers' practices.

A number of individuals played extremely important boundary-spanning roles in the YV. CIMMYT agronomist Ivan Ortiz-Monasterio linked the research community (including the Stanford team, local university researchers, and government researchers) with innovative producers. This role was not mandated by CIMMYT and therefore, depends on his commitment to it. Through his interactions with farmers and researchers, he built mutual trust and credibility that allowed him to become a conduit for ideas, approaches, and feedback to and from farmers and researchers. As the fertilizer example makes clear, the development and testing of new management approaches that make sense environmentally and economically proceeded through multilinked and iterative interactions among the research community, innovative farmers, credit unions, and farmers in general, often with key individuals at the center.

As shaped by its strongest actors, the YV knowledge system has for many decades served a green revolution agenda. That is, the most powerful organizations (credit unions and the NARS) have focused primarily on improving yields of a few cereal crops, with a slight shift to profitability in response to Mexican policy reforms of the 1980s and 1990s. These powerful organizations serve the typical farmers' interests quite well, perhaps excluding those who are not well-connected to the knowledge systems (poor, collective farmers who function outside of credit unions or are members of weak credit unions, agricultural laborers, and nonagricultural interest groups). Many of the ejido peasant farmers are distant from the channels that disseminate agricultural research to farmers and the channels that advocate farmers' interests to researchers and policy makers.

With increasing challenges in the agricultural sector and growing demand for water, environmental protection, and improved public health, voices of other groups in the region are beginning to be heard. Nongovernmental bodies and groups from outside the region, including researchers and their funders, are also influencing research priorities. Research that provides new information about agriculture's offsite impacts (e.g., research linking phytoplankton blooms in the Sea of Cortez directly to fertilization and irrigation events in the YV) can influence the dialogue between actors in the knowledge system, empowering those who bear the costs of agriculture's offsite impacts and creating space for dialogue about how to mitigate such impacts. If researchers seek to produce relevant knowledge that ultimately influences decision making, they must recognize the dynamics of the knowledge system and participate purposefully and strategically in it.

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