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Contribution of farmers' experiments and innovations to Cuba's agricultural innovation system

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Abstract

Innovations are the driving force for agricultural development under present diverse situations of uncertainty. The innovation system perspective acknowledges the contributions made by all stakeholders involved in knowledge development, dissemination and appropriation. According to the specific agricultural production system, farmers adopt innovations, modify them or innovate on their own. This paper examines the role of farmers' experiments and innovations in Cuba's agricultural innovation system (AIS), identifies knowledge exchange encounters and describes some strategies implemented to institutionalize farmers' experiments and innovations. The research methods comprised 34 semi-structured interviews with agricultural experts from the science, administration and advisory system, and 31 free list questionnaires to assess the institutional influence on farmers' experiments and innovations. In addition, three case studies of outstanding farmers' experiments are presented. The results suggest that the government's commitment to social participation in knowledge development provides the basic prerequisite for an effective integration of farmers' experiments and innovation in Cuba. The historically conditioned vertical structure of knowledge development and dissemination is gradually changing toward more horizontal procedures. The dynamic exchange of ideas at all kinds of interactive meetings, such as workshops or farmers' field schools, have favored farmer to farmer learning as well as knowledge sharing with research, academic and extension officials. This multi-stakeholders' approach contributes to institutionalize farmers' knowledge. Farmers' experiments and innovations play a major role in improving farm management and thereby can contribute to build resilience at the farming system level as well as for the national agricultural system.

Key words: innovation, farmers' experiments, knowledge system, agricultural innovation system, participation

Introduction

The worldwide food crisis[1], food insecurity[2], expected drastic impacts of already ongoing climate change on agricultural production[3] and immense migration phenomena of former rural people, including farmers, to cities[4] have brought politicians, scientists and the civil society to rethink conventional agricultural practice. The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) has demanded an urgent need for change to improve the efficiency and sustainability of food production[5]. Global change calls for strategies to support the innovative capacity of rural people in improving agricultural production based on their traditional ecological knowledge[6].

Innovation, in general, is widely accepted to be a driving force for development. Increasingly, scientists and extension agents recognize the key role of innovative farmers and acknowledge their experiments and innovations for agricultural development[7–10] and for farming systems' resilience[11,12]. Farmers hold a crucial position because they test the feasibility of agricultural innovations and adapt them, if necessary, until they fit to local conditions. However, the capacity of farmers to develop valuable innovations on their own is still frequently underestimated and their contribution to formal research and development

agendas often remains neglected. Nevertheless, farmers' experiments and innovations have been part of agriculture over thousands of years and were driving forces for development[9,13,14]. Nowadays, the innovative capacity of farmers, research activities of scientists and other stakeholders engaged in rural development increasingly merge and lead to participatory research and development approaches. The most common attitude of scientists and extensionists toward traditional knowledge and technology transfer is gradually shifting to more participatory approaches. Such participatory views typically improve efficiency and applicability of research outcomes[15–22]. However, research and development in agriculture are embedded in a complex framework of underlying conditions (e.g., political, administrative or financial) that directly influence the nature of farmers' experiments and innovations[23].

Cuba's economy and society face special circumstances because of its geographic location and history. After the Revolution in 1959, the Cuban government favored intensive production systems using a high proportion of foreign inputs and top-down knowledge and technology transfer[24]. Trade relations with the former socialist countries in Eastern Europe that were established in the early 1960s and the United States trade embargo shaped the basic conditions for research and development in agriculture. The collapse of the socialist block in 1989 led to major changes that had a drastic impact on the economy and society[25]. Resource scarcity turned into an ever-present constraint for Cuba's agriculture and triggered the shift toward more sustainable ways of production, including the establishment of local food systems and a more ecological approach in agriculture[26].

Cuba's long history with public participation in innovation development, the current innovation policy and the national legislation shape the boundaries of the agricultural innovation system (AIS). National legislation for agriculture regulates the distribution of farm land, prices, the establishment of trade relationships to foreign suppliers or costumers, input supply and the commercialization of agricultural commodities. As a result, the agricultural sector is relatively closed and intensively controlled. This makes farmers' experiments and innovations in Cuba and their potential within the AIS unique to study.

We hypothesize that farmers' endogenous potential to experiment and innovate constitutes a valuable contribution to knowledge and technology development. Agricultural policy, scientific research and the formal advisory system can strengthen farmers' experiments and innovations if they do consider them as valuable elements in the domestic AIS. We will not be able to prove that farmers' experiments and innovations are crucial to prepare agriculture for global change, but we do claim that they play a significant role in Cuba's AIS and are probably often ignored in many other parts of the world.

In this paper, we examine the role of Cuban farmers in knowledge and technology development, and their contribution to and integration into the AIS. After briefly introducing the key concepts and providing a conceptual framework for the study, we draw attention to Cuban farmers' knowledge and information system. In addition, we present evidence of farmers' experiments and innovations in Cuba and their institutional linkage. Finally, we describe strategies to institutionalize farmers' experiments and innovation.

Methods

Field research in Cuba was conducted following the methodological framework of a research project about organic farmers' experiments. The project was carried out in Austria, Cuba and Israel by three PhD students. The study was aimed at generating empirical knowledge on the processes whereby organic farmers experiment and innovate, and how they generate new knowledge. In this paper, we concentrate on selected results from that study. Data collection in Cuba was carried out in 2007 and 2008 for 5 months each year. During this period, 34 expert interviews, based on a semi-structured interview guide, were conducted with representatives of research institutions, agricultural administration, the advisory system, farmers' organizations and international development agencies[27]. The selection of the interviewees was based on purposeful sampling combined with snowball sampling[28]. Recommendations of local counterparts from research institutes helped in selecting appropriate interviewees. The selection criteria included their expertise in the fields of farmers' experiments and innovations, agricultural extension and organic farming. A semi-structured interview was applied to cover topics such as the institutions' mission and objectives, the institutions' information and knowledge systems, the interviewees' perception of farmers' experiments and innovations, sustainable agriculture and organic farming in Cuba. In addition, 31 free lists[29] were collected to assess the institutional influence on farmers' experiments and innovations.

The interviews lasted between 45 min and 2 h, depending on time availability of the respondent and the willingness to share information. For analysis of secondary data, newspaper and magazine articles, brochures, proceedings of events and other relevant media publications were revised. Although expert interviews were an integral part of data collection, field research was primarily focused on farmer interviews to study the farmers' perception of experimenting and innovating[30]. Thus, a total of 69 semi-structured interviews with farmers were conducted from which three selected examples of farmers' innovations were analyzed for this paper.

Each interview was recorded with a digital voice recorder, transcribed with Express Scribe software, coded and analyzed using the software Atlas.ti. Interview data were revised according to a content analysis approach, based on a combination of deductive and inductive coding. Pre-defined codes and emerging codes were assigned to text chunks with similar content. Codes were organized into code families to obtain thematic categories[28–32]. Working with farmers as key informants permitted additional

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insights into farmers' perceptions of their experiments. Participant observation completed the set of methods to gain additional insights into farmers' participation in scientific and semi-scientific conferences, innovation award forums, innovation fairs, workshops, seminars and farmers' meetings. During all events, selected relevant phases were digitally recorded and protocols were elaborated and analyzed in the same way as described for the interviews[29].

Definition of AIS

There are different commonly used definitions of 'innovation', depending on the discipline involved. The innovation system approach defines an innovation as 'doing something new by using existing or novel knowledge in new ways'[33]. In the agricultural context and at farm level, an innovation is considered 'something new that started within the lifetime of a farmer'[34]. This means that an innovation is new for the individual but can already be known by others, while an invention is an absolutely new idea or technology that has been discovered or created for the first time[35].

The innovation system approach reflects the interactive and social character of an innovation and provides an understanding of the dynamic processes involved. An innovation system includes stakeholders at governmental and non-governmental levels, their interactions and contributions to the development, the dissemination and application of knowledge and/or technology. AIS stakeholders may include multinational and national agribusinesses, as well as small-, medium- and large-sized ones, individual stakeholders, cooperatives, farmers' organizations or other community-based groups at the market level, national and international research institutes, extension services, government marketing agencies, higher-education institutions and non-governmental organizations (NGOs). All of them interact on the basis of market and non-market relations[36].

The smallest AIS units are individual stakeholders, such as farmers or farm workers, and stakeholder groups, such as farm households or rural communities[37]. These units either develop or adopt innovations and knowledge and eventually put them into practice. Consequently, they determine whether an innovation is developed enough to suit local conditions or whether it requires further adaptation to such conditions[38].

Knowledge and its development, dissemination and appropriation play a key role in innovation systems. Knowledge development is a process of constant feedback between empirical observation and interpretation of the observed[39]. However, knowledge is more than the simple accumulation of information. It is characterized by its applicability and usability[40]. It can be classified into scientific and local knowledge. Scientific knowledge is accumulated by systematic study, is codified and explicit. Local knowledge, by contrast, is generated over time and consists of accumulated experiences, practices and beliefs. It evolves from adaptive processes, is implicit and passed on orally or by shared practical experiences[41]. Knowledge, in general, can be embodied in a technology, a commodity or a service, or it can be detached and appear in a method or practice[42]. Every type of knowledge is specific to a certain production sector; hence, the agricultural sector relies on a site-specific knowledge base. Knowledge exchange encounters[43] are important to increase the availability of information and to provide learning opportunities for the stakeholders involved in innovation processes. Innovation and knowledge are complementary concepts since the development of an innovation leads to the development of new knowledge. Vice versa, the appropriation of new knowledge potentially leads to an innovation. Therefore, those farmers' activities that eventually lead to innovations and/or to the development of new knowledge can be labeled as 'farmers' experiments'.

The term 'farmers' experiments' means the 'research conducted by farmers for the discovery or generation of information'[44]. Farmers' experiments usually aim at testing the validity of a hypothesis or trying something new. Throughout the long history of agriculture, farmers have developed lots of technologies and built up specific knowledge bases for their respective local environments[45]. Thus, informal research by farmers can be a major source of agricultural innovations[46–49].

Results

General description of Cuban farmers' knowledge and information system

Knowledge and information are basic AIS elements. Personal communication and individual interaction facilitate learning processes, adaptation and development of new knowledge. Knowledge develops either from external information sources or from own activities that include a learning component, or both. Cuban farmers derive external information from other farmers, extension agents and scientists as well as from the media. Communication with other farmers is a valuable source of information because it is usually based on similar communication and livelihood patterns which result in trust and mutual understanding.

Scientific institutions, represented through their staff members, spend considerable time, effort and resources to transfer technologies; however, farmers often have to adapt and reformulate them to their own local conditions. Knowledge exchange between scientists and practitioners is crucial to accept the challenge of agricultural production under limited economic conditions.

Formal extension services. Extension agents of the Ministry of Agriculture (*Ministerio de la Agricultura*, MINAGRI) at municipal level, associated with the state-owned agricultural enterprises and local staff members of the National Small Farmers' Association (*Asociación Nacional de Agricultores Pequeños*, ANAP) form the more active bodies that provide information and technical assistance for farmers. Other important sources for agricultural advice at local level are the 73 territorial stations belonging to the National Center for Plant Health

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Table 1. Distribution and number of ANAP members[50,51].

Type of cooperative production	No. of cooperatives	No. of members	% of total workforce in agriculture[1]	% of total cultivated land[2]
CPA	1089	62,494	7%	10.2%
CCS	3242	269,380	28%	17.9%
Total	4331	331,874	35%	28.1%

CCS, Cooperatives of Credits and Services (*Cooperativa de Créditos y Servicios*); CPA, Cooperatives of Agricultural Production (*Cooperativa de Producción Agropecuario*).
[1] Total workforce in agriculture, forestry, hunting and fishing: 945,600.
[2] Total cultivated land: 2,988,500 ha.

(*Centro Nacional de Sanidad Vegetal*, CNSV) and the Centers for the Reproduction of Entomophage and Entomopathogens (*Centros de Reproducción de Entomófagos y Entomopatógenos*, CREE), both working in close relationship with the Plant Health Research Institute (*Instituto de Investigaciones de Sanidad Vegetal*, INISAV). INISAV maintains a network of territorial stations and deals with plant protection. Each station employs about ten extension agents in charge of providing services to individual farmers and cooperatives. They make field visits and organize workshops, seminars and courses according to local and national demands. Extension agents make use of audiovisual material such as short videos, computer presentations and leaflets. However, elaboration of written material to inform farmers is limited because plant protection personnel face resource shortages. Thus, oral knowledge prevails in most extension situations.

Each municipality counts on several extension agents who assist individual farmers and cooperatives. In addition, there are research entities distributed all over the country, even in the most remote areas, close to farmers. The topics covered by these institutions can include pest and disease control, seed and soil management and, to a lesser extent, irrigation, processing and marketing.

Although Cuba's agricultural administration is engaged in improving transfer of technology and extension services, delivery efficiency is still a challenge. Potential end-users of agricultural innovations frequently could not properly access useful results from formal and informal channels. Thus, farmers' attempts to adopt innovations are less effective than they could be. This dilemma has been internalized by the Ministry of Science, Technology and the Environment (*Ministerio de Ciencia, Tecnología y Medio Ambiente*, CITMA), which commissioned the Center for Local and Community Development (*Centro de Estudios de Desarrollo Local*, CEDEL) to elaborate an inventory of highlighted innovations and inventions of Cuban research institutions. Also, remarkable inventions of farmers are mentioned in the inventory. This 'Catalog of Technologies for Local Development' aims at increasing awareness of innovations among farmers and extension agents and thereby contributes to the dissemination of new and site-appropriated agricultural knowledge. Structure and language of the catalog are clear and concise and therefore guarantee the utility for potential end-users. However, final implementation of the technologies and methods presented in the catalog will, certainly, strongly depend on the willingness and competence of the local government and agricultural administration. A farmer's role is to assess the applicability and feasibility of the innovations for site-specific conditions.

ANAP is a member of the transnational peasant movement, La Via Campesina, that defends small farmers' rights. ANAP is the most widespread institution for knowledge dissemination among farmers in Cuba. It runs offices in all municipalities, represents farmers' interests before the government and, simultaneously, is the government's vehicle to disseminate relevant information. ANAP represents all farmers belonging either to Cooperatives of Credits and Services (*Cooperativa de Créditos y Servicios*, CCS) or Cooperatives of Agricultural Production (*Cooperativa de Producción Agropecuario*, CPA). The Cooperatives of Credits and Services are associations of farmers who own their farmland or have acquired the land in usufruct. The members of Cooperatives of Agricultural Production collectively own the farmland (Table 1).

Both cooperatives organize a monthly meeting where all members are asked to participate to talk about topics such as cooperative administration, technical issues or agricultural policy. One ANAP representative usually participates in the cooperative meeting to inform farmers about relevant news in agriculture. Thus, information provided by the ANAP reaches every farmer. Its nationwide structure assures an educational and training program that comprises 117 training sites distributed throughout the island and a national center located in the province of Havana.

Farmer-to-farmer extension. An example of horizontal dissemination of knowledge is the Agroecological Farmer-to-Farmer Movement (*Movimiento Agroecológico de Campesino a Campesino*, MACAC), initiated by ANAP in 1997. Each municipal office of ANAP employs a representative who coordinates and supervises all activities related to the movement. The main pillars of the farmer-to-farmer movement in Cuba are those participants who become 'facilitators' and 'promoters'. Facilitators usually have a high education standard, good communication skills, hold broad knowledge in agricultural issues and some of them are agricultural technicians. They often

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promote the introduction of agroecological innovations, assist farmers during the experimental stage of adoption, organize workshops and coordinate farm visits. Cooperatives that choose to employ a facilitator pay for the service. However, facilitators are not typical extensionists, since they usually live in rural areas and most of them are farmers themselves. As for promoters, they are farmers themselves and their colleagues admit that they are research minded, enthusiastic experimenters and eloquent communicators. They experiment with promising technologies or practices and search for local solutions for specific challenges. Promoters open their farms for field visits and are willing to share their knowledge with their peers, using the farmer-to-farmer approach.

The movement spread rapidly all over Cuba and is famous even beyond the borders of the country. About 110,000 farmers' families have joined the movement since its implementation and now represent more than one-third of all ANAP members[52]. The success of the farmer-to-farmer methodology reflects ANAP's willingness to support a participatory, dynamic and bottom-up movement with agroecology and farmers' experiments as a basic condition.

In addition to formal extension services of ANAP, the farmer-to-farmer movement provides an organizational framework for the horizontal diffusion of farmers' agroecological experiments and innovations. It plays a key role in facilitating knowledge exchange among farmers, providing agricultural training and education and offering extension services.

Although the ANAP is the leading organization of farmer-to-farmer extension in Cuba, there are other accompanying institutions and organizations, such as the National Institute of Agricultural Science (*Instituto Nacional de Ciencas Agrícolas*, INCA). This research institute has been working since 1999 with farmers, encouraging them to experiment. Local staff members invite farmers to participate in the so-called Center for Local Agricultural Innovation (*Centro Local de Innovación Agropecuaria*, CLIA). Periodically organized encounters for knowledge exchange such as training courses, workshops or seed exchange fairs have been crucial elements for farmer-to-farmer and farmer-to-scientist interaction. Other institutions that offer extension services and encourage knowledge exchange among farmers are the Cuban Association of Agricultural and Forest Technicians (*Asociación Cubana de Técnicos Agrícolas y Forestales de Cuba*, ACTAF) and the Cuban Association of Animal Production (*Asociación Cubana de Producción Animal*, ACPA).

Urban agriculture. Urban agriculture is a special case in the extension service and knowledge exchange system. The government has been supporting urban agriculture since the early 1990s due to its positive contribution in overcoming the economic and food crisis. The National Group for Urban Agriculture (*Grupo Nacional de Agricultura Urbana*, GNAU) was created in 1997 to assure its growth and to strengthen its development. Each municipality runs an office that coordinates the urban agriculture activities, including organization, administration, extension services, etc. Urban agriculture extensionists typically live close to urban gardens and normally share similar knowledge and viewpoints with farmers. Establishing rapport takes place in a natural way and eventually helps improving efficiency of their work.

Mass media. The formal advisory system frequently uses mass media as a cost-effective means to reach a wide range of farmers and, simultaneously, to go easy on available resources. Agriculture-oriented TV programs and news from radio broadcasting or newspapers make information accessible to farmers living in remote areas. Some experimental stations of INISAV even run their own radio programs. In some cases TV or radio programs include reports on farmers' experiments and innovations. A remarkable example of knowledge dissemination using documentaries is the Program for Local Agricultural Innovation (*Programa de Innovación Agropecuaria Local*, PIAL), a development project implemented by INCA.

Training for extension agents. Extension agents play a key role in Cuba's AIS. Despite the lack of an articulated and universal extension service in Cuba, there is considerable social capital and intellectual potential to cover the needs of the agricultural sector. Keeping them up-to-date through further education and capacity building improves the efficiency of knowledge dissemination. ACTAF pursues knowledge exchange by providing training and education to extension agents and other professionals throughout the country. With branch offices in each province and about 23,000 members all over the country, it is one of the most important associations for technicians in the agricultural sector. ACTAF frequently organizes workshops on a cooperative basis, conferences and seminars and publishes books and a magazine on sustainable agriculture and organic farming. Another important organization is ACPA, also with some 20,000 members, which emphasizes knowledge exchange, facilitates access to agricultural information and provides capacity building, education and extension services. Other organizations, such as the Cuban Association for Sugar Cane Technicians (*Asociación Cubana de Técnicos Azucareros*, ATAC), cover a more specialized knowledge domain.

All these initiatives and platforms contribute to increase the farmers' agricultural knowledge pool. However, bureaucracy and top-down mentality are historically caused and are part of many governmental institutions, including research entities and extension services. This situation has changed slightly over the past two decades but occasionally lowers the flexibility and efficiency of extension services. Thus, Cuban farmers' informal communication networks are indispensable channels for knowledge dissemination and exchange.

Farmers' experiments and innovations in Cuba

During the so-called 'special period' (from 1990 to the present time) Cuban farmers have had to become more

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innovative to overcome the economic and food crisis. Cuba's government started to support new and sustainable technologies (e.g., biological pest control and organic fertilizer production) and reorganized the agricultural structure (e.g., farm diversification, downsizing of large farms and offering of land in usufruct). Government officials encouraged farmers to experiment with sustainable agriculture practices. Farmers, in turn, had little other choice than experimenting with low-input agriculture. Besides the government and farmer approaches to optimize rural farming, urban dwellers became increasingly engaged in food production and initiated the urban agriculture movement in Cuba. Farmers' experiments and innovations turned out to be an indispensable element to alleviate the effects of the crisis. Cuban farmers and city dwellers engaged in agriculture chose to experiment to maintain and increase the agricultural output. Thereby, they were able to guarantee the greater part of the basic food supply.

Also today, farmers' experiments and innovations prove to be important for Cuba's agriculture. Most Cuban farmers are involved in activities that can be called 'farmers' experiments'. However, there are large differences between experiments in terms of complexity, intensity, chronology, degree of participation and degree of consciousness. Some experiments and innovations might remain undetected because even the farmers themselves do not pay attention to small improvements in their daily farming practice. Farmers' experimental methods strongly depend on both their personal background and the kind and closeness of their relationships with scientists or extension agents. Those who are willing to present their experiments to a public audience generally use more sophisticated methods for conducting and evaluating them. These farmers often rely on the support from extensionists or scientists to elaborate a report and to prepare a presentation. Although some outstanding farmers conduct highly complex experiments by using scientific or semi-scientific methods, most of the experiments are simple and easily manageable. Farmers usually choose a pragmatic approach to experimentation and adapt or adjust the methods during the experimental process in order to achieve applicable results. Particularly, research-minded farmers are enthusiastic experimenters and are busily engaged in experimenting and trying out new things, whereas rather passive farmers avoid worrying about experimenting or else their experiments date back a long time. The outcomes of farmers' experiments primarily serve the purpose of improving a given current situation. Most farmers' experiments and innovations bear upon the local context.

Experiments and innovations are a fundamental part of farmers' working routine, independent of scientists' acceptance or support. They are natural ways of accumulating experience and enhancing the farmers' local knowledge. By experimenting, farmers improve farm management and contribute to agricultural development in the ways they already have been practicing for centuries.

Highlighted examples of farmers' experiments and innovations. In this section, we describe and analyze three cases of innovative farmers and present some of their most relevant results as evidence of their contribution to the Cuban AIS.

Casimiro and his multi-plough. Casimiro, a former policeman, lives in Sancti Spíritus province, in the center of the island. He owns a 10 ha farm and cultivates a variety of different crops and keeps livestock. Crop cultivation on his farm has always been labor intensive because of animal traction using either the American iron plough or the wooden Creole plough. Thus, reducing the workload was the farmer's motive to assess possibilities for building a plough on his own. Casimiro began to search for discarded but suitable iron parts that served him to build a new version of a plough for animal traction. During 3 years of experimentation with different shares he adapted the tool, step by step, to his farming conditions. Continuous observation and intermediary evaluation of the plough's performance in the field accompanied the experimentation process. Finally, Casimiro developed an iron plough with 28 different usages for tillage and weed control that helps him to save labor and costs by increasing the operating speed. Initially, the farmer was not aware of the potential of his multi-plough until a local MACAC representative took notice of his invention and started to promote its dissemination.

The farmer received Cuba's national innovation award at the Science and Technology Forum and participated in numerous national and international conferences where he presented his invention. With a strong holistic view of farming system management, Casimiro is widely known among agronomists and farmers not only for his multi-plough but also for his achievement in environmentally friendly farming. Many people visit the farm, including national and international delegations, governmental officials, agronomists, farmers and students. Up to date he has participated in 54 interviews for radio programs, TV programs and magazines, and often elaborates his own documentaries on his novel farming practices and philosophical views. His book about agroecology and family farming is an inspiration for other farmers and the Cuban society to better understand agroecology.

The irrigation system of Franchi. Franchi lives in Havana province and takes part in the urban agriculture movement. Before farming he worked in the construction industry. He owns a small plot of land within a small village and mainly produces cuttings and young plants that require abundant water. Buying an irrigation system would have been too expensive and very difficult to acquire. The visit to the farm of a colleague who owned an expensive irrigation system triggered his enthusiasm in finding a low-cost solution for irrigation. Franchi went through a long period of thinking and reflecting about the feasibility of a self-made irrigation system. Always convinced that building an efficient and cheap irrigation system would be possible, one day he had the idea that the

water itself has to open and close the water tap to save energy. He worked 2 years on the device using discarded materials until his efforts were finally converted into a much-noticed invention.

The main elements of the system are a recycled plastic bottle, recycled drip tubes from a hospital and a counterbalance based on hydraulic principles. Drip tubes determine the time to fill up the bottle. When the bottle is full it turns over and opens a water tap and thereby starts irrigating until the bottle is empty again. Duration of irrigation depends on the time the water requires to leak out and is controlled by drip tubes. When the bottle is empty it turns back to the original position, closes the water tap and starts filling again. This irrigation system works without electricity or fossil energy and requires a minimum of attendance, and thus supports the farmers' commitment to organic farming and sustainable agriculture.

Franchi obtained a patent for his irrigation system and participated in the Cuban innovation award forum. However, initially he faced skepticism from some prestigious scientists who underestimated the potential of a farmers' invention. Others, in turn, immediately recognized its great potential and supported the farmer to disseminate his irrigation system. Up to now he has received countless visitors including ministers, scientists and students, from Cuba and abroad. The farmer participated in numerous national and international conferences and traveled abroad several times to present his invention. Further, radio stations and TV stations broadcasted programs and newspapers and magazines published articles, on this experience. Research institutions and universities bestowed an honorific title upon him and occasionally invite him to give a talk.

Effective micro-organisms (EM) at Omars' farm. Omar lives in Varadero, Matanzas, a 2-h car journey east from Havana city in one of the most touristic areas of Cuba. He owns a farm, located some 15 km away from his home. As in the previous examples, farming was his response to the economic crisis after the collapse of the socialist system. He holds an academic degree in chemistry and worked as a teacher before starting his farm business. Omar has always been interested in learning new things and participated in a workshop for the elaboration of EM organized by the Experimental Station 'Indio Hatuey' (EEIH). The innovative farmer decided to produce EM on his own and obtained hermetic closable tanks. He started to look for basic raw materials that included micro-organisms in a wild area. Then he prepared a solid and a liquid mixture and filled the barrels for anaerobic fermentation. The application of EM led to very good results and they turned into an indispensable element on Omar's agroecological farm. After several experiments he was able to verify the positive effects. One experiment was the application of EM to assess the effects on rabbit nutrition. The farmer applied scientific methods to conduct and analyze his experiment. He is one of the very few farmers who know how to work on a computer and how to document his research process. Thus, researchers also acknowledge the scientific validity of his results. His conclusion was that the application of EM in rabbit production has a positive effect on the animals' health. Omar has already presented these and other results in scientific and semi-scientific conferences, in farmers' conferences and in the innovation award forum. He participates in the MACAC and uses the movement as a platform to disseminate his results. Omar is one of the most outstanding agroecological farmers in his province and therefore receives frequently national and international guests and maintains regular relationships with scientists and research centers.

The three cases provide evidence of farmers' experiments and farmers' participation in knowledge and innovation development. They indicate a general openness of the domestic AIS for participation of the civil society. These farmers and their innovations are widely known by other farmers and experts in Cuba. They are conscious about their experimental activities and spend more resources on experimenting than other farmers. However, such highly innovative farmers are a minority. Despite the fact that other farmers also develop and present notable innovations, few of them achieve the high publicity. Many farmers' innovations are valid for the specific local context but transfer to another context is difficult. Therefore, farmers' native capacity to experiment is the precondition to find own solutions for emerging problems and thereby to contribute to the domestic AIS.

Farmers' experiments and innovations and their linkage to agricultural institutions

Cuba's agricultural sector is highly regulated and institutionalized. Consequently, the agricultural institutions also influence farmers' experiments and innovations. The aim of the free-list exercise was to assess institutional influence on farmers' experiments and innovations. The interviewed experts mentioned 62 different institutions—or generic terms for institutions—that are known to influence farmers' experiments and innovations (Table 2). The most frequently mentioned institutions were ANAP and INCA.

Links between farmers and agricultural officials. ANAP represents private farmers and runs the MACAC, building on farmers' experiments as a core element of the whole movement. The high rank of INCA as a government body is an indicator of the success and importance of the PIAL. These two institutions determine the debate about farmers' experiments and innovations in Cuba to a large extend. However, with the method used to identify such a complex system linked to innovation, it is difficult in practice to accurately define the very nature of the institutions' influence on farmers' experiments and innovations. In many different forms, to some extent all the aforementioned institutions—whether governmental or not—have an effect on farmers' experimental processes and innovations. Many agricultural research institutions, farmers' organizations and development agencies, with

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Table 2. Institutional influence on farmers' experiment and innovations. Institutions that are known by the respondents as influencing farmers' experiments and innovations ($n = 31$), including frequency of mention (f), percent of respondents (%), average rank (r) and Smith S (s).

Institution	Acronym	*f*	%	*r*	*s*
National Small Farmers' Association	ANAP	26	81	5.1	0.542
National Institute of Agricultural Science	INCA	24	75	5.4	0.499
Cuban Association of Agriculture and Forestry Technicians	ACTAF	19	59	7.3	0.329
Cuban Association of Animal Production	ACPA	18	56	7.6	0.273
Institute of Animal Sciences	ICA	15	47	7.2	0.269
Agricultural universities		15	47	7.9	0.159
Ministry of Agriculture	MINAGRI	11	34	2.5	0.305
Agricultural state enterprises		11	34	7.7	0.157
Ministry of Science, Technology and the Environment	CITMA	11	34	6.3	0.147
National Research Institute of Tropical Agriculture	INIFAT	10	31	4.4	0.235
National Research Institute of Plant Health	INISAV	10	31	6.3	0.188
National Research Institute of Tropical Roots and Tubers	INIVIT	10	31	7	0.184
Horticultural Research Institute 'Liliana Dimitrova'	IIHLD	10	31	8.5	0.155
National Center of Animal and Plant Health	CENSA	10	31	7.5	0.155
Soil Research Institute	IIS	8	25	5.9	0.154
Experimental Station 'Indio Hatuey'	EEIH	8	25	8.8	0.106
Pastures and Forages Research Institute	IIPF	7	22	7.7	0.128
Ministry of Higher Education	MES	7	22	5.3	0.105
Agricultural Delegation		7	22	6.4	0.103
People's Power Assembly	APP	6	19	4.5	0.103
Forum on Science and Technology	FCT	6	19	6.5	0.081
Rice Research Institute	IIA	5	16	9.2	0.086
National Association of Innovators and Rationalizers	ANIR	5	16	9.8	0.058
Agricultural Research Institute 'Jorge Dimitrov'	IIAJD	5	16	14.6	0.02
Research Institute of Tropical Fruit growing	IIFT	4	13	3.3	0.099
Granja Urbana	GU	4	13	7.8	0.065
Technical Youth Brigades	BTJ	4	13	11.8	0.038
Ministry of the Sugar Industry	MINAZ	3	9	2.7	0.075
Irrigation and Drainage Research Institute	IIRD	3	9	4.7	0.074
Swine Research Institute	IIP	3	9	9.7	0.055
Poultry Research Institute	IIA	3	9	10.3	0.052
Coffee and Cacao Research Station	ECICC	3	9	12.7	0.043
Cuban Communist Party	PCC	2	6	1	0.063
Research Institute of Agricultural Mechanization	IIMA	2	6	2	0.06
Tobacco Research Institute	II TABACO	2	6	9.5	0.042
Apiculture Research Institute	II APICOLA	2	6	11	0.038
Antonio Núñez Jiménez Foundation of Nature and Man	FANJ	2	6	5	0.036
Forestry Research Institute	IIF	2	6	11	0.034
Institute of veterinary medicine	IMV	2	6	14	0.031
Cooperative and Farmers Sector of the Ministry of Agriculture		2	6	4	0.028
Cuban Women Federation	FMC	2	6	7	0.027
Agricultural University of Havana	UNAH	2	6	10	0.02
Agriculture Polytechnic Institutes	IPA	2	6	14,5	0.004
Ministry of Economy and Planning	MEP	1	3	1	0.031
National Union of Arquitects and Construction Engineers of Cuba	UNAICC	1	3	4	0.023
Research Centre of Animal Improvement	CIMA	1	3	9	0.022
Unity of Extensionism and Research in Agronomic Science on sHolgin	UEICA-H	1	3	4	0.02
Centre for the Reproduction of Entomophagous and Entomophatogens	CREE	1	3	6	0.019
Swiss Agency for Development and Cooperation	COSUDE	1	3	8	0.017
Welthungerhilfe	AAA	1	3	9	0.015
Basic Unit of Cooperative Production	UBPC	1	3	8	0.014
Ministry of Foreign Investment and Economic Cooperation	MINVEC	1	3	7	0.014
ACSUR Las Segovias	ACSUR	1	3	10	0.013
Unity of Science and Technology	UCT	1	3	8	0.011
Norwegian Peoples' Aid	NPA	1	3	11	0.01
Center for Genetic Engineering and Biotechnology	CIGB	1	3	19	0.01

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Table 2 (Continued)

Institution	Acronym	*f*	%	*r*	*s*
Program for Local Human Development	PDHL	1	3	12	0.008
Polo cientifico		1	3	4	0.008
Pastures and Forages Experimental Station 'Sancti Spiritus'	EEPFSS	1	3	10	0.006
Local Development Centre	CEDEL	1	3	10	0.006
Association of Sugar Cane Technicians	ATAC	1	3	7	0.004
Centre of Psychological and Sociological Research	CIPS	1	3	11	0.003

ANAP and INCA leading the way, encourage farmers to experiment and to innovate. Local staff members of centers for plant health, research institutions, ANAP offices and agricultural enterprises usually share a common understanding about the local production conditions with farmers. Further, the income gap and class distinctions are negligible and contribute to approximate farmers and advisors. Thus, the relationship is often characterized by trust and empathy. This is accurate not only for extension services but also for participatory research projects.

Participatory research. Participatory research in Cuba refers to scientific or semi-scientific research conducted in cooperation with farmers on their own fields. Farmers and their specific knowledge about the local environment are central actors in the research process. Participatory research is an upcoming approach in Cuba's agricultural science and builds on farmers' capacity and willingness to experiment. Increasingly, representatives of research institutes and the academic agricultural education sector invite farmers to participate in research projects or in the elaboration of MSc and PhD theses. The high density of educational institutions and the easy access to them favor the interaction between farmers and scientists or students, who often live in rural neighborhoods and therefore share a similar background with the farmers. Thus, most of the research relationships are characterized by trust and mutual understanding. Farmers' participation mainly includes technology assessment or feasibility evaluation of innovations introduced from outside, e.g., new varieties, organic fertilizers, erosion control methods, etc.

Probably, the most successful example of participatory research in Cuba has been the Participatory Plant Breeding Project (*Proyecto de Fitomejoramiento Participativo*, FP) launched by INCA in 1999. INCA's scientists offered seeds to farmers and encouraged them to conduct experiments, to assess the suitability of different varieties for specific farming conditions and to follow their own perceptions of what sustainability is. In 2007, the FP project merged into PIAL, expanding the original concept. At present, the project encourages farmers to experiment on any topic of interest and pays more intense attention to socio-economic and environmental issues involved with agriculture (i.e., farmers' empowerment, gender issues and climate change). This program has been successful in engaging practitioners looking for their own solutions with the support of project staff members at each so-called Center for Local Agricultural Innovation (*Centro Local de Innovación Agropecuaria*, CLIA). It strengthens individual farmers and cooperatives willing to experiment with new agricultural technologies or to innovate on their own and facilitates widely the dissemination of their own results. PIAL is a development project financed and supported by international development agencies with INCA as the local counterpart that is linked to a broad network of institutions. Four main principles have been basic to reach the objectives: access to biological and technological diversity, farmers' empowerment and decision making, transferability of results and acknowledgement of recognizable environmental and socio-economic achievements.

Other institutions with national impact on agricultural innovation, which have emphasized farmers' participation in their research projects, are, for example, INISAV, the National Institute for Basic Research on Tropical Agriculture (*Instituto de Investigaciones Fundamentales en Agricultura Tropical*, INIFAT) or the National Research Institute for Tropical Roots and Tubers (*Instituto Nacional de Investigaciones de Viandas Tropicales*, INIVIT). Most of the research projects include an on-farm research component with different levels of farmers' participation, depending on the researchers' and the farmers' willingness to collaborate. The role of farmers in such projects focuses on the assessment of technologies and practices in their own farms as well as participation in group discussion and local, national and international events.

Institutionalizing farmers' experiments and innovations

By experimenting and innovating, farmers contribute to knowledge development. Knowledge exchange encounters provide opportunities to integrate farmers' experiments and innovations into Cuba's AIS and thereby are conducive to mutual learning among the diverse actors. Knowledge exchange encounters allow farmers to communicate their experiences to other farmers, the scientific community and to extension agents.

The farmers' purpose is food production to sustain family livelihood. Thus, experiments and innovations are usually a side effect of farming activities, and few farmers are conscious and active experimenters who are willing to spend additional resources on experimentation. Nevertheless, experimenting is a key element in food system

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functioning and adaptation to change. Incorporation of farmers' knowledge and expertise into formal research agendas leads to organizational learning and institutional benefits. With farmers' participation, the applicability of research results increases and the immediate social impact of research projects is enhanced. Evidence of the rapport among researchers, academics and extension agents is that all respondents who worked directly with farmers could mention at least one farmers' innovation and were open minded toward farmers' contribution to the AIS. This suggests an encouraging climate toward the institutionalization of farmers' experiments and innovations and that a great part of the scientific community in Cuba acknowledges farmers' contributions to knowledge and innovation development.

The Forum of Science and Technology. The long history of ambivalent relations with the US government and the US trade embargo triggered the first tendencies to liberate Cuban industry from the US Ernesto Che Guevara founded an association to organize the production and reproduction of spare parts. Later, and based on Guevara's attempts, the National Association for Innovators and Rationalisers (*Asociación Nacional de Innovadores y Racionalizadores,* ANIR) was founded to represent all Cuban citizens who successfully innovated, invented or contributed to rationalize production.

For many years the participation of the civil society has been part of Cuba's innovation policy. The Forum of Science and Technology, created in 1983 by Fidel Castro, has been for years the best-established movement for knowledge exchange and institutionalization of farmers' innovations. All Cuban citizens are encouraged to participate and to present their innovations or inventions to a wider audience. A committee of experts awards relevant innovations in 13 different sectors, including food and agriculture. The forum starts at the local level and ends at the national level. Institutions of the agricultural sector (e.g., INCA, ANAP, ACTAF, agricultural state enterprises, etc.) organize their own forums and select the most relevant works to be presented at the higher level. The various forums for the food and agricultural sector provide platforms for farmers, farm workers and agricultural scientists to present their experiments, innovations and inventions. The municipal offices for statistics collect all awarded contributions and the CITMA recently started to compile them on a central database. ANAP is in charge of the organization of the forum for the private farming sector and the Agroecological Farmer-to-Farmer Movement has given rise to a high degree of agroecological farmers' experiments and innovations presented at the forum.

In case of inventions, the author has to apply for a patent at the Cuban Office for Industrial Property (*Officina Cubana de la Propiedad Industrial*, OCPI). If the invention is developed at the place of employment, the government guarantees the author's property rights but reserves the right for commercialization. Otherwise, the person who develops the invention holds the right to inhibit commercial use. Non-commercial use is allowed anyway.

The biodiversity fairs. An interesting platform for knowledge exchange is the so-called 'biodiversity fair' which was initially organized by staff members from INCA working on the FP project. Farmers who experimented with seed varieties assembled to exchange seeds and experiences. The fairs quickly became social events called 'biodiversity festivals', where children, women and other social groups got involved. It included traditional singers, competitions of dishes made with novel bean or corn varieties and other traditional foods. Participants accepted the fairs so well that during the course of the project, farmers started to organize fairs on their own. Even if some fairs are organized by farmers themselves, usually scientists and extension agents participate and provide support. Like this, the project became a process with its own dynamics and led to about 40,000 beneficiaries all over Cuba. Staff members usually document the fairs and local media occasionally takes up the topic for publishing.

Farmers' participation in conferences. Farmers' participation in national and international conferences is a promising approach for institutionalizing farmers' experiments and innovations. The main purpose of inviting farmers to conferences is to facilitate knowledge exchange between them and scientists. Several Cuban institutions organize conferences with farmers' participation on a regular basis. ANAP and ACTAF organized conferences where farmers' presentations—mostly based on their experiments and innovations—made up over 80% of the total. Their participation included poster presentations, panel discussions or even as keynote speakers in plenary sessions. The organizing committees compile farmers' experiments and innovations and publish print or digital versions of the proceedings[53].

Characterization of Cuba's AIS. Cuba's AIS is embedded in a contextual framework that shapes the properties of the system and the nature of innovation processes (Fig. 1). Cuban policy provides the legal basis for agricultural institutions to facilitate farmers' experiments and innovations. Agricultural institutions, whether scientific or non-scientific, are embedded in a network of interconnected relations with each other. Relations are based on material exchange, such as funding, and non-material exchange, such as services or information. Socio-economic conditions refer, for instance, to resource scarcity, the US trade embargo or income levels. The bio-physical context of the island includes weather and soil conditions, the duration of the growing season but also droughts, heavy rainfalls or hurricanes. These conditions influence farmers in their decision making and their scope of action, and potentially trigger self-determined experimentation. Innovation is the core element of the AIS, interconnecting knowledge development, dissemination and appropriation. In other words, an innovation is the vehicle that transfers new knowledge from one actor in the AIS to another. Farmers and scientists are involved in

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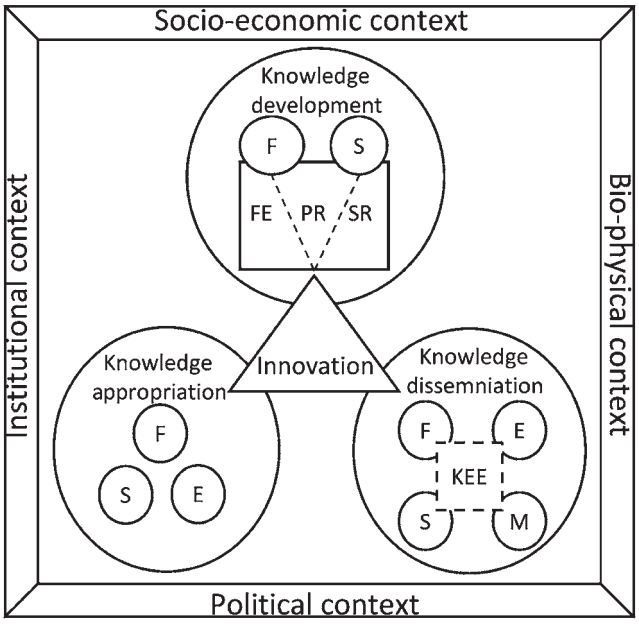

Figure 1. Cuba's agricultural innovation system. F, Farmers; S, Scientists; E, Extensionists; M, Media; FE, Farmers' Experiments; PR, Participatory Research; SR, Scientific Research; KEE, Knowledge Exchange Encounter.

knowledge development. Farmers conduct informal experiments on their farms and scientists conduct formal research in laboratories or experimental plots. Both increasingly work together in participatory research projects building on farmers' local knowledge and their native capacity to experiment and innovate. Informal, formal and participatory research potentially lead to innovations. Knowledge exchange encounters play a key role in terms of dissemination and institutionalization of farmers' innovations. Extension services, media, scientists and farmers themselves actively disseminate agricultural knowledge and innovations. Efficiency of dissemination strategies and accessibility to information sources influence knowledge appropriation. AIS stakeholders use novel knowledge to put it into practice, to multiply it or as a starting point for further formal or informal research that can result in further innovation. The end-users of innovations manage a specific amount of new knowledge, whether embedded in a technology or not, and integrate it into their existing local knowledge base. This integration gives rise to a new, hybrid and evolving form of knowledge.

Discussion

Since the Cuban revolution succeeded, the government has aimed at establishing a society in which marketability and profitability of innovations are of secondary importance. The trade embargo soon led to first initiatives to sever the Cuban economy from the US The creation of the National Association for Innovators and Rationalisers and the foundation of the Forum of Science and Technology have been crucial milestones in the process of socializing knowledge and innovation development.

Education has been free of charge and compulsory up to an age of 16 and has led to the high literacy rate of more than 95%. The average level of education is the ninth grade and more than half a million Cubans hold an academic degree[54]. The establishment of university centers in municipalities has enhanced educational chances and has contributed to decrease the gap between scientists and the working class. These educational strategies have reinforced farmers' innovative capacity and provided favorable conditions to open science for the public.

Thus, political leaders appeal to the citizens to take on a responsibility for technological progress and development. Research issues are first defined by local citizens and then discussed by local research institutes and universities. Ministries take up the proposals, evaluate and prioritize them. That approach guarantees a high level of individual engagement in the decision-making process for research priorities[55]. A sense of public ownership for research has developed. The result is a new ethic of science that is in contrast to the capitalist approach. In capitalist systems, scientific research is funded with the wealth of the public but research institutions demand the supremacy of knowledge. In addition, the private sector increasingly funds projects and tries to commercialize research findings for maximization of profits and often at the cost of farmers. Capitalist systems disregard social participation but on the contrary favor the concentration of knowledge and innovations in the hands of a minority[56]. The results of this study show that Cuba's government has chosen a more participatory approach to research and development than capitalist countries have done. The political decision makers, pursuing socialist ideals, recognized the social dimension of science and technology and have made innovation development a public concern. The socialization of knowledge is conducive to a more equitable society. However, even if innovation development is socially founded, hierarchical structures sometimes overshadow participatory approaches.

The collapse of the socialist block triggered the urgent need to react to resource constraints and enhanced the tendencies to achieve technological autonomy and food sovereignty. The agricultural policy, research and extension services were forced to adapt to a new situation. The economic crisis was associated with fundamental changes in the agricultural sector that concerned the partial transformation of state farms into Basic Units of Cooperative Production (*Unidad Básica de Producción Cooperativa*, UBPC) and into New Type State Farms (*Granja Estatal de Nuevo Tipo*, GENT). Further, the government distributed farm land in usufruct to peasant farmers, encouraged local and small-scale food production and supported the rise of urban agriculture. All these changes were accompanied by an increase in autonomy for on-farm decision making[57]. With more autonomy, farmers' willingness to assume

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personal responsibility increased. Individual initiatives led to informal experimentation and eventually to the development of appropriate technology. This study reveals that the historically caused changes in the agricultural sector called for coping strategies. These strategies were based on a combination of the government's commitment to social participation in the domestic AIS and farmers' potential to experiment and innovate.

Apart from direct policy measures to facilitate social participation in the AIS, the Agroecological Farmer-to-Farmer Movement and the Program for Local Agricultural Innovation additionally have upgraded farmers' experiments and innovations in Cuba. The incorporation of the ANAP into the transnational movement La Via Campesina strengthens the importance of agroecology and the farmer-to-farmer methodology for peasant movements on an international level. ANAP has promoted agroecology for more than 10 years and is therefore qualified to coordinate the Division for Sustainable Peasant Agriculture within La Via Campesina. One of ANAP's tasks is to identify, study, analyze and document the most advanced and positive experiences of agroecology. The aim is to share the lessons with other member organizations all over the world[58]. Thus, the potential of farmers' experiments and innovations, as an integral part of the Agroecological Farmer-to-Farmer Movement, are in line for widespread appreciation.

Conclusion

Opportunities for knowledge dissemination and exchange shape the nature of Cuba's AIS. Personal interaction between the stakeholders and encounters for open discussion favor knowledge transfer. Cooperative meetings, workshops, conferences and the Forum of Science and Technology itself are crucial platforms that facilitate the communication of farmers' experiences to the public and further contribute to institutionalize them. As these events start on a local level and sometimes even include the international level, they help improve the spread of innovations and new agricultural knowledge among farmers, extension agents and scientists. Hence, the Cuban example demonstrates how farmers' experiments and innovations can be integrated into functional AIS in such a way that farmers' innovative capacity is fully recognized.

Cuba's administrative and institutional structure provides several platforms for farmers to exchange and spread knowledge, though on occasion the lack of flexibility of such platforms lowers the diffusion of innovations. Although agricultural extension and the media play a crucial role for knowledge dissemination, the potential end-users of agricultural innovations are often unaware of the results achieved by formal and informal research. The respondents claimed that the diffusion of innovations mostly depend on local initiatives and mainly remain a farmers' domain. Thus, the personal communication networks are crucial for dissemination of knowledge and innovations.

The Cuban example illustrates how raising farmers' participation helps to build up a socially based knowledge pool and leads to agricultural development. Although farmers' participation in agricultural research and development is an upcoming approach, the top-down conventional mindset still prevails among scientists, extension agents and policy makers. Providing a proper environment and policy incentives for farmers' active participation, and recognition of farmers' own experimentation and innovation capacity, will help them develop their full potential within the AIS. Political commitment to research, education and social participation in agricultural development is an effective way to upgrade the efficiency of the AIS. However, it should be made clear that a national policy can only build the general framework for the integration of farmers' experiments and that further integration will depend on local decision makers, who directly interact with farmers. Therefore, agricultural decision makers should actively involve farmers in knowledge and technology development.

The innovative capacity of individuals and groups is a powerful element of AIS that can contribute to the system's resilience. Favoring farmers' experiments might help to increase the adaptive capacity of farmers. The heterogeneity of roles and interactions of the different stakeholders within the AIS determines the capacity to respond to external changes and therefore can help to build systems' resilience.

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