
PRACTICE BRIDGE

From technology transfer to innovation-based rural development: A necessary turn at the Indio Hatuey experimental station

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The collapse of the socialist bloc in the early 1990s led to a severe economic crisis in Cuba, unleashing various processes of change to confront the situation. One such process involved taking a new look at the role of the scientific sector in the management and development of science, technology and innovation, and moving from a reductionist approach to a holistic, endogenous and territorial one. This article describes a process of change that occurred at the Indio Hatuey Experimental Station for Pasture and Forage, or EEPFIH, an experimental station for research and education in Matanzas province, Cuba. This article also presents environmental outcomes obtained on farms as a result of this new approach, and institutional outcomes such as the creation of new structures making it possible to address issues such as food security and sovereignty, sustainable agriculture, and climate change at the local and provincial levels. These transformations allow the EEPFIH to respond effectively to the demands of Cuban society in collaboration with other institutions, implementing practices that stimulate these institutions to play a central role in managing their development. More horizontal spaces for exchange and innovation have been opened up, and new mechanisms for management established, consolidating alliances and connections among actors at different levels. *Please refer to Supplementary Materials*, DOI: <https://doi.org/10.1525/elementa.325.s1>, for a full text Spanish version of this article.

Keywords: Endogenous development; Territorial rural development; Innovation; Knowledge production; Agroecology; Governance

El derrumbe del campo socialista a principios de los años 90 provocó una crisis económica severa en Cuba que desencadenó varios procesos de cambio para enfrentar la problemática. Uno de estos fue repensar el rol del sector científico en la gestión y desarrollo de la ciencia, tecnología e innovación, y llevarlo desde un enfoque reduccionista a un enfoque holístico, endógeno y territorial. Este artículo describe el proceso de cambio que se produjo en la Estación Experimental de Pastos y Forrajes de Indio Hatuey (EEPFIH), estación experimental de investigación y docencia en la provincia de Matanzas en Cuba. Además, presenta resultados ecológicos obtenidos en fincas producto del nuevo enfoque de trabajo y resultados institucionales como la creación de nuevas estructuras, que permiten enfrentar problemáticas de seguridad y soberanía alimentaria, agricultura sostenible y cambio climático a nivel local y territorial. Las transformaciones logradas permitieron a la EEPFIH responder eficazmente a demandas de la sociedad cubana en integración con otras instituciones mediante la implementación de prácticas que estimulan el protagonismo de estas instituciones en la gestión de su desarrollo. Se abrieron espacios de intercambio e innovación más horizontales y se establecieron nuevos mecanismos de gestión que consolidan las alianzas y vínculos entre actores a distintos niveles. *La versión en español de este artículo se puede encontrar en Materiales Suplementarias*, DOI: <https://doi.org/10.1525/elementa.325.s1>.

Palabras clave: Desarrollo endógeno; Desarrollo territorial rural; Producción de conocimiento; Agroecología; Gobernanza

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Introduction

The collapse of the socialist bloc, the unviable economic model implemented in Cuba, the devastating effects of hurricanes, and the U.S. blockade against the island, in addition to changes in the world economy of the 1990s, unleashed numerous processes of change in the Cuban economy. These changes were aimed at bolstering flagging economic activity levels.

Some of the principal transformations promoted were: opening up to foreign investment through the creation of joint enterprises, with Cuba maintaining majority control; legalizing the possession of foreign currency; and recognizing the private sector as a new economic actor, with the goal of freeing up the state from a major part of its role producing goods and services. Wages were frozen to reduce the negative effects of the crisis on workers, and a new convertible currency was created (the Cuban convertible peso, or CUC) and put into parallel circulation. In addition, a new law established general principles and taxes as the basis of Cuba's tax system, and steps were taken to reduce subsidies and budget spending and to increase tax income from the state sector. At the same time, and with the goal of stimulating increased agricultural production for domestic consumption, farmers' markets were promoted, people were granted access to idle lands in usufruct, and Basic Units of Cooperative Production, or UBPCs, were created out of dismantled state enterprises (González, 1995).

This new context forced the scientific sector to rethink the management of science, technology, and innovation in Cuba. The main obstacle identified was the sector's reductionist approach. Influenced by Rene Descartes, this approach laid the foundations of modern scientific rationalism, holding that to understand and become familiar with a complex problem, the problem must be reduced to its simplest parts (Sarandón and Flores, 2009).

Scientific reductionism thus perpetuates and reinforces a fragmented and scattered conception of the world that is then generalized; hence the development of the idea that each small compartment of knowing and doing is independent from others (Viniestra-Velázquez, 2014a). Reductionist scientific discourse not only has little relevance for solving humanity's great problems, such as growing exclusion of large segments of the population or the devastation of ecosystems, it also contributes decisively to maintaining economic and social inequality in the world (Viniestra-Velázquez, 2014b).

Positivism (or the idea that only scientific proof counts as valid knowledge) marked the development of modern science as the sole form of knowledge production until the mid-20th century (Álava and Orellana, 2014). This approach, which significantly contributed to humanity's scientific and technical progress, now faces difficulties in explaining many systems, including those of agricultural production and the especially complex systems of campesino production, where it is impossible to understand overall conduct without an interrelated consideration of its constituent components and complex interactions (Venegas and Siau, 1994). This is why new paradigms have emerged in recent years, such as complexity theory,

systems theory, participatory methodologies (Álava and Orellana, 2014), and agroecology (Paleologos et al., 2017).

Given this reality, it was urgently necessary to adopt a new approach that would prioritize the restoration of natural resources and ecosystems where productive agricultural systems operate, and also foster the business economy and family management as an essential component for Cuba to attain food sovereignty. Implementing this new approach required the involvement of institutions such as the Science and Technology System, the Ministry of Agriculture, and the Agricultural Education System. These institutions were not in a position to provide answers, given that they generally took the same reductionist approach (Machado et al., 2009) that served as a guide to the agricultural development model adopted in Cuba, that is: Green Revolution as a paradigm that functioned by supplying machinery and other agricultural inputs imported at preferential prices from the European socialist bloc.

Nevertheless, in this context, many Cuban institutions strove to expand their capacity to respond to the changing context of the national economy. It was necessary for "the institutional transformation initiative to have the goal of changing the people who change things, instead of changing things (products, services, and processes) so that people will change later" (Álvarez et al., 2005, pg. 70), including and considering an alternative that would value the improvement of everyday life in rural communities associated with agricultural production.

In this sense, Albuquerque and Pérez (2013) suggest that Latin America and the Caribbean are in a long stage of technological transition and economic and social restructuring, where the key variables are: 1) the incorporation of innovations in the productive fabric of each territorial sphere; 2) higher qualification of human resources according to local needs; 3) attention to local environmental characteristics; and 4) institutional adaptation that requires new forms of management together with existing organizations (private or public), among others. In Cuba, this should be achieved through applying new work techniques and methodologies that bring with them important transformations in prevailing management practices and systems. In this way, processes of structural change responding to these demands will require an effective and efficient approach to restructuring within their own territorial scenarios, and not abstractly.

This article aims to demonstrate the most relevant results obtained in the process of transforming the EEPFIH, and how it accompanied local communities and agricultural production entities in their search for new ways of approaching technology transfer as a component of territorial and rural development. This process involved the appropriation of new concepts and social constructs for more innovative actions as a key factor in favoring socio-economic transformation processes in these contexts.

The case of the Indio Hatuey Experimental Station for Pasture and Forage

The Indio Hatuey Experimental Station for Pasture and Forage (EEPFIH), founded in 1962, devoted its efforts until the 1990s to obtaining varieties of pasture and forage and

technologies for producing them, as well as developing new types of feed for cattle, with an emphasis on technology development.

Beginning in 1996, as it took into account changes to the Cuban context stemming from the economic crisis triggered by the loss of the country's markets, which demanded new perspectives for analyzing the economy and production, the EEPFIH found that the sustainable development of the country's agricultural sector would require a review of paradigms, theoretical frameworks, and strategies for intervention in science management. Based on that premise, it was decided to incorporate socio-economic and environmental studies as a line of work at the institution, and to bring research closer to farms and communities.

In 1999 the Socio-Economic Group (now the Local Sustainable Development Group) was created as part of the EEPFIH, and it began working to support agricultural development in the municipality of Martí in Matanzas province (in Cuba's central region), and subsequently in other municipalities of the same province. The group worked with a socioeconomic and technical-productive perspective, testing methodologies based on techniques developed by the International Union for Conservation of Nature (IUCN, 1997), the New Paradigm Network¹ (De Souza Silva et al., 2005), and Cuba's Ministry of Economy and Planning, together with the EEPFIH (Machado et al., 2008).

The Martí municipality was selected to begin investigations using the new constructivist approach² (developed by the above-mentioned methodologies), taking into account the following factors: a) Martí was one of the Matanzas municipalities most affected by the economic crisis; b) cattle raising is its main economic activity; c) it had every category of landholding legally allowed at that time in Cuba; and d) very importantly, it borders the municipality where the EEPFIH is located, taking into account that the economic crisis also affected the availability of resources for research and development, making it especially difficult to travel long distances.

During this stage, a participatory diagnostic was carried out with representatives from different social sectors of the Martí municipality (residents, technicians, business people, officials, and researchers from the EEPFIH and local academic institutions). This was accompanied by the implementation of a municipal development strategy that included the creation of programs and projects for socioeconomic, institutional and agricultural productivity improvement as a way of making changes in the areas of business, cooperatives and farms, and communities.

This work made it possible to better understand the local reality in its social, economic, and environmental dimensions and move toward a contextual and constructivist view of rural development, recognizing the coexistence in a single social space of multiple realities, all dependent on the perception of different actors in development, with an emphasis on creating human capacities, both in the institution and in its sphere of influence. The EEPFIH then adopted the perspective of a systemic approach to development (Machado et al., 2009), requiring overall progress

in the economic, productive and social, as well as environmental and human, areas (Pichs, 2002).

This desire for progress led the institution to modify its initial mission (i.e., research for pasture-based cattle farming, prioritizing the development and evaluation of pasture and forage crops to overcome the limitations of naturally-existing pastures in Cuba), and make it much broader. The new vision aspired to contribute to local sustainable development through agroecological models that would integrate the production of food and energy for fostering socioeconomic development, environmental protection, and human well-being with gender equality. With this new mission, three goals were set: economic growth, equity (social, economic, and environmental) and environmental sustainability (Dourojeanni, 2000; Asnar and Barrón, 2017). This made it possible for the institution to make recommendations better suited to the settings of its work.

As part of this work, between 2000 and 2013, studies were conducted on four agricultural cooperatives, examining the role played by leaders in the productive process and the relationships within the community, the productive entity, and local government, based on the social behavior of subjects involved in the development process (see Miranda et al., 2002; González, 2003a, b; Machado et al., 2009, 2013; Mesa and Machado, 2009; Suset et al., 2007; Suset et al., 2013). Important experiences involving the participation of municipal social actors, especially in Martí municipality, included programs for training, diagnostics and participatory development planning as part of an institutional project financed by the Matanzas provincial office of the Ministry of Science and Technology with the objective of learning about economic, social, and environmental problems and proposing novel solutions. The studies found that one main reason for such a slow recovery to the 1980s standard of living indicators was the persistence of social behavior dependent on an external context. This was the product of the "culture of waiting" created by the paternalistic approach to development prior to the crisis (Machado et al., 2009).

The research confirmed that the agricultural production entity's lack of perceived responsibility for the community that maintained it was limiting the municipality's development as a consequence of natural resource management based on sectorial rather than territorial development (with respect to production) (Suset, 2011).

Working in networks with other institutions and the private productive sector

In an environment of change and economic crisis, various research and development institutions at the national level joined emergent efforts to promote development at the local scale. As part of those efforts, in the first decade of the 21st century, and in the context of EEPFIH studies in its line of research on agrarian and local sustainable development, a Local Center for Agricultural Innovation, or CLIA, was created to facilitate multi-sector participation in the design, construction, implementation and evaluation of local technologies for incorporation into the local agricultural sector.

The CLIA is part of an especially innovative initiative called the Local Agricultural Innovation Program, or PIAL. This program is coordinated by the National Institute of Agricultural Sciences (INCA) and is supported by international cooperation from the Swiss Agency for Development and Cooperation (COSUDE) (Miranda, et al., 2012). The PIAL initiative began by promoting participatory plant breeding as an essential process for obtaining seeds that are suitable, adapted, and resilient for local areas, as a way of ensuring food security and sovereignty. After 17 years of evolution and four stages of implementation, the result today is the Local Agricultural Innovation System, or SIAL, which is much more far-reaching than the PIAL project in its early years. The SIAL is a rural development initiative that seeks to contribute to food sovereignty based on campesino experiments and the articulation of components and processes in the interest of participatory innovation management. The SIAL brings together producers, both women and men, and representatives of government, scientific research centers, universities, and associations as part of a multi-actor coordinating platform to strengthen decision-making and impact at the municipal level in a decentralized way, from the ground up (Ortiz Pérez, 2013, 2016). In this section we describe the experience of the EEPIH in this process since the second stage of the PIAL (beginning in 2008).

The CLIA, created in 2008, accompanied the transformation of 25 campesino farms that were members of nine Credit and Service Cooperatives (CCS)³ in eight municipalities of Matanzas province. Through this relationship, new concepts were explored regarding the “context-centric” model for building knowledge, in which the fusion of knowledge allows for greater contextualization, transdisciplinarity, ethics and participation in transformations that are carried out (De Souza Silva et al., 2005).

In the initial stage (2008–2011), work was focused on production systems diagnostics, facilitating access to biological diversity, and sharing information to help create networks related to food security, agroecology, and climate change. The premise of these new networks was that the introduction of any innovation in a production process would be efficient as long as producers were associated from the start with the new procedures and management of the innovation itself.

At that time, farms connected to this work lacked diversity, with none possessing more than 23 species, and their soils were of medium and low fertility. In addition, none of them had a forestry component integrated into their animal production systems. The predominant livestock was bovine, and milk production ranged from three to five kg per cow per day. Cattle farming and the use of synthetic nitrogen fertilizers were the main sources of greenhouse gas emissions.

Given this situation, it was necessary to facilitate a transformation toward production systems that would permit future generations to earn a living based on cooperation and caring for nature, by designing productive environments characterized by the diversity, stability and resilience of natural ecosystems. The first task was to meet the demand for training on technical aspects of sustainable

agriculture and livestock management, while at the same time strategies were drawn up for changes to provide a response to specific problems identified (Miranda, et al., 2010).

Over a period of four years, more than 500 direct beneficiaries were trained at events led by producers and, in the process, the principles of the “Campesino-to-Campesino” (“Farmer-to-Farmer” or “Peasant-to-Peasant”) methodology were reassessed. This participatory, simple methodology allows most activities to be led and run by farmers, both women and men. It is a participatory way of promoting and improving campesino production systems based on principles of participation and empowerment (Machín Sosa et al., 2010). In this sense, participants promoted exchanges, farmer experimentation, and visits to different successful experiences, allowing for a harmonious construction of objective responses adapted to the problems of local communities, farms, and production systems, while also helping to identify new individuals interested in novel practices. The training was presented as a process for modifying producers’ knowledge, abilities, and know-how.

Joint work by producers and technicians made it possible to diversify farm production areas in stages. The herbaceous layer was made more diverse by introducing varieties of grasses and climbing legumes that made those systems more productive, with higher yields and higher quality available biomass per unit area. This made it possible to increase milk production to values of 6 to 8 kilograms/cow per day (Sánchez et al., 2011). At the same time, “Diversity Fairs”⁴ organized by producers at the local level facilitated the participatory dissemination of 74 species of grains, grasses, and vegetables.

Gradually, 80 hectares devoted to animal production were transformed, 43 of which are in production, enabling these farms to be more productive. In these spaces, the improved grasses of 12 herbaceous forage species were introduced, along with 115,000 trees from seven highly nutritious arboreal forage species. At the same time, 4,780 timber-yielding trees and 25 fruit tree species were disseminated and established, with the goal of diversifying productive activities on these farms. The use of bioproducts and cover crops were promoted as alternative practices for protecting soil.

This diversity of species and varieties helped increase the volume of vegetative cover and forest areas on farms, fostering the environmental services generated by these ecosystems, such as carbon sequestration, diversity, integrated management of system components, and reforestation. These latter two services led to a leap in emissions reduction and carbon sequestration on these farms, which increased from 10 to 42 t per hectare compared to the baseline year of 2007 (**Table 1**).

An emphasis was placed on connecting environmental and socioeconomic variables that represented greater well-being for families. At the same time, the innovation systems developed facilitated the articulation (i.e. organization) of actors, taking into account local knowledge and producers’ needs as substantial elements in the collective generation of alternatives for food production.

The creation of the SIAL

Within the framework created through the integration of the PIAL and the aforementioned EEPFIH experiences, strategic planning⁵ was carried out for two of the province's municipalities and all of their Central State Administration Entities, whether or not they were subordinated to a Municipal Administration Council.⁶ The strategic planning process took as its reference point the Comprehensive Development Program,⁷ which outlined the projected transformations.

Taking into account the consistency of this proposal with that of the Local Agricultural Innovation Program (PIAL), work began to support local communities with the implementation of their Comprehensive Development Programs by creating and consolidating a

Local Agricultural Innovation System (SIAL) to articulate (tangible and intangible) components and processes for participatory innovation management (**Figure 1**). All of this made it possible to respond to local demands for agricultural development upon the basis of local capacities.

Through this process, different actors have joined together (e.g., producers, research centers, universities, representatives of local government and of central state administration entities) to identify and implement strategies, projects, and programs for local development. In addition, the project's actions have been inserted into the municipal institutional fabric through the creation of the Multi-Actor Management Platform (PMG), and the Agricultural Innovation Groups (GIAL). The PMG and GIAL's carry out their efforts in physical spaces where actors are encouraged to learn and interact, and to effectively and actively manage and lead agricultural development in a given territory by identifying challenges and common interests.

The Platform, or PMG, is a strategic space for the negotiation of the Comprehensive Municipal Development Program, which is organized into programs and subprograms. Within the PMG framework, the territory's socio-cultural and institutional projects are articulated, and strategic areas are identified and debated with the goal of facilitating high-impact activities related to food production, energy, and environmental protection. These strategic areas are then further refined into proposals for local development projects that are presented to and approved by the Municipal Administration Council.

Table 1: Change in the number of trees, density of plants, and stored carbon on 25 farms that participated in CLIA interventions**. DOI: <https://doi.org/10.1525/elementa.325.t1>

| Period | Number of trees | Density (plants/ha.) | Stored forest C (t of C/ha.)* |
|--------------------|-----------------|----------------------|-------------------------------|
| Before CLIA (2007) | 46 | 1.4 | 10 |
| After CLIA (2011) | 3,546 | 107.5 | 42 |

Source: Miranda et al. (2011).

* Calculated according to Mercadet and Álvarez (2005).

** Local Center of Agricultural Innovation.

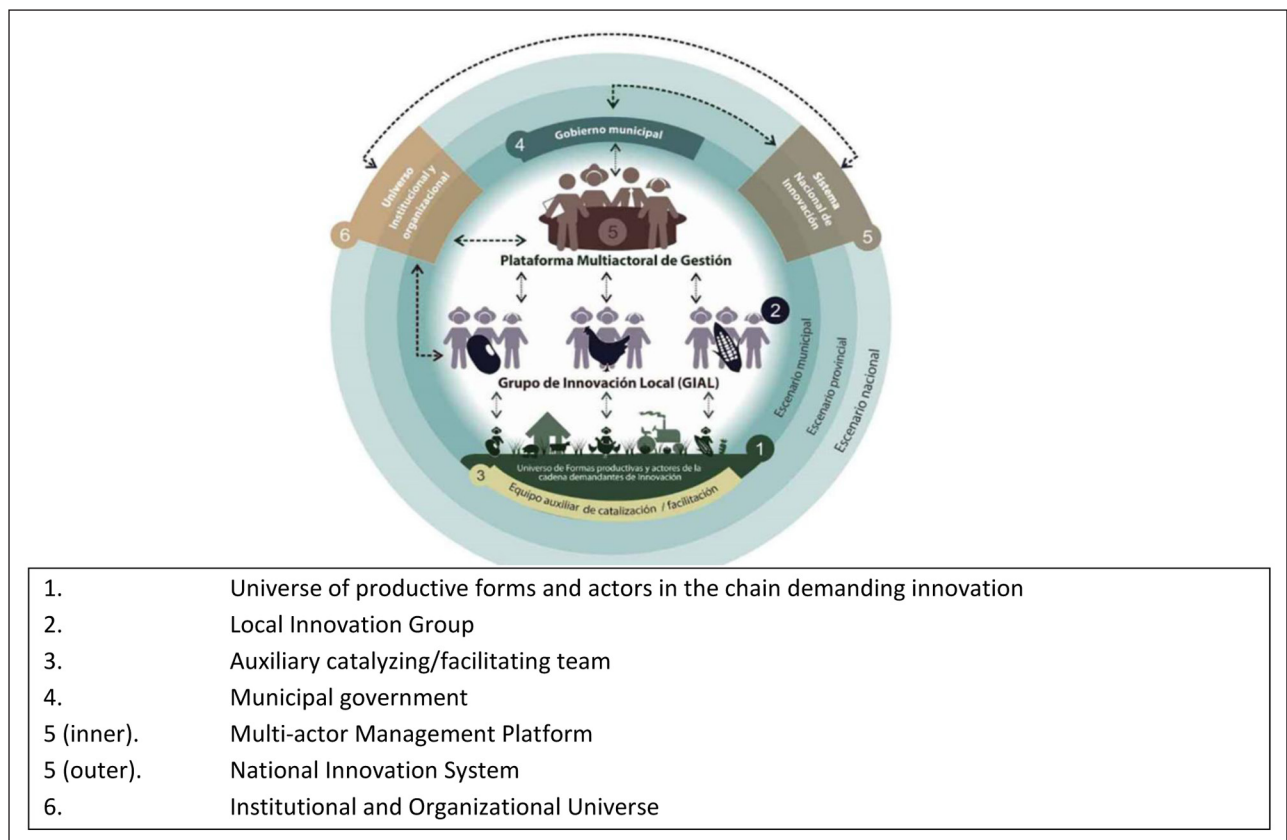


Figure 1: Diagram of the Local Agricultural Innovation System (SIAL). Taken from Ortiz, 2016. DOI: <https://doi.org/10.1525/elementa.325.f1>

While the emphasis was primarily placed on Matanzas' agricultural sector, efforts were directed toward a more holistic proposal highlighting a systemic approach, so as not to disregard any of the actors who make local development possible. As a result, it was possible to promote learning-in-action processes that mobilized actors in the production and service sectors.

Simultaneously, competency training programs are being managed and promoted to ensure the necessary capacities for implementing development processes. This work is done by the Knowledge and Innovation Management Group (anchored at the local university)⁸ as part of the functions that the Ministry of Higher Education has entrusted to its provincial teaching units through its University Management of Knowledge and Innovation for Development Program. This group's mission is to contribute to processes of knowledge production and adoption, with a focus on meeting people's needs through processes of participation and implementing a system to evaluate the impacts of economic, social, cultural, and environmental development in the province.

The starting point for local innovation, then, is the need to address specific agricultural or non-agricultural challenges, which are resolved through interactive learning that effectively combines scientific and local knowledges, which are of strong quality in Cuba given the high education level of its population, including among farmers.

This work has permitted the emergence of new initiatives and government support for economic activities in non-state production and services, with the goal of promoting local production chains and fostering the management of this transformation through learning, where combining new practices with local wisdom can achieve the formation of competencies (technical, managerial, and human). At the same time, these can positively influence multiple social spaces for innovation that emerged from collective efforts.

New challenges for science in Cuba

In order to achieve coherent responses from within academia, efforts are needed to reach an equilibrium between intensive or basic science and science connected to production, the economy, and society. This translates to moving from a policy centered on science to a policy centered on innovation. With a new innovation focus, the development of projects based on investing money to obtain knowledge would become about investing knowledge to obtain economic returns (Díaz et al., 2014).

A territorial development framework considers all geographic space to be an open and complex system; therefore, economic growth in a territory is exogenous, while social progress is endogenous. From that premise, the aim becomes to "endogenize" development rooted in local potential, based on processes of negotiation focused on the local context (Díaz et al., 2014; González et al., 2013). To do so requires a change in institutions and organizations in the academic/institutional sphere. Competencies must be formed among researchers and technicians to consolidate a model of innovation that is not designed to transfer scientific knowledge to campesinos in a linear

way, because that is insufficient for strengthening their own management capacities. It is a question of complementing the knowledge and contributions of science with local capacities for managing their practical application through joint action. In this way, it will be possible to build new proposals to be disseminated spontaneously among a significant mass of innovators in every setting that science aims to reach (Ortiz et al., 2014).

Conclusions

The adoption of a systemic focus, wherein human beings are the focal point for transformation and are included as leaders of interventions, has allowed the EEPFIH to become an institution capable of effectively meeting the demands of Cuban society in an integrated way in collaboration with other academic, governmental, and non-government institutions. Understanding the need for new ways to promote transformation has enabled institutions to modify the way they see themselves within their territory, and their commitment to the process of managing its development.

Efforts aimed at creating new ways of managing knowledge have made it possible to open up more horizontal spaces for exchange and innovation, and to establish new mechanisms for planning and management that stimulate the consolidation of alliances and linkages amongst local actors. These new ways of managing knowledge and spaces for horizontal exchange and innovation are essential to effectively address problems of sustainable local development.

Notes

¹ "Based on its central theory that humanity is undergoing a change of era and not an era of change, the New Paradigm Network of the International Food Policy Research Institute, financed by the Swiss Agency for Development and Cooperation, puts forward a 'different' proposal for institutional innovation. The Red demonstrates that global changes now occurring do not belong to the era of industrialism; rather, they are creating another historical era. The Red assumes that the role of institutional innovation should be to change the 'persons' who change things, different from technological innovation that changes 'things' to change people. Technological innovation favors the 'hard' aspect of reality; institutional innovation favors its 'soft' aspect, constructed on the basis of ideals, values and beliefs, principles and promises, laws and policies, rules and roles, decisions and actions by human beings. The Red proposes to us a very particular way of interpreting institutional reality and of intervening to transform it, with implications for innovation and cooperation." (De Souza Silva et al., 2005, p. 7).

² The constructivist approach assumes many realities exist, all dependent on the perception of different actors, and that this perception is built from relationships among phenomena. It also holds that any intervention should be negotiated.

³ Credit and Service Cooperatives are a type of producer cooperative wherein members independently manage

production on their own lands but come together as a cooperative to access and share credits, services, infrastructure and markets.

- ⁴ Fairs to demonstrate plant diversity (of any crop, or of animal species), organized by campesinos in a particular region or municipality, or by a specific campesino, with the goal of stimulating productive diversification.
- ⁵ Strategic planning is the drafting, development and implementation of different operational plans by enterprises and organizations with the goal of reaching projected objectives and goals. These plans may be short, medium or long-term.
- ⁶ The Municipal Councils of Administration supervise local economic, production, and service entities with the purpose of meeting the needs – economic, health and other services, education, culture, sports and recreation – of everyone who lives in the territory under each of their jurisdictions. They are the municipal form of government in Cuba.
- ⁷ Municipal Comprehensive Development Program, PDIM. Initially, this program was a model for proactive planning by territories to transform their problems by using local potentialities and opportunities, but with financial backing from the Ministry of Economy and Planning. It was implemented in 10 of the country's municipalities on an experimental basis, with the support of local, provincial and national institutions. While the State subsequently was incapable of financially supporting all of these plans, they have become a powerful tool in the hands of municipal governments that must determine how to invest scarce available resources. The PDIM is created in such a way that all projects, activities, actions, and resources are directed to fulfilling the objectives outlined in them, whether they are economic, social, environmental, or institutional.
- ⁸ In Cuba, the “universalization of education” policy led to the creation of municipal university centers, or satellite campuses, affiliated with provincial universities. In this case, the local university campuses are affiliated with the University of Matanzas.

Acknowledgements

Authors would like to thank Roger Orlando Hernández, Ramiro Ruíz Ruíz, Tatiana Tabío Villaurrutia, Katia García Martínez, Noraida Nodarse Coto, Walfrido J. Chaples Valle, Anier Hernández Martínez, Geyuski González Flores, Daniel Vela de León, Gilberto Blanco García, Juan Carlos Lezcano Fleires, Frank David Tirado García, Giraldo J Martín Martín, Mercedes Falcón Perdomo, Taymi Figueroa Peguero, Raquel Pérez Cano, Aida I Cruz Martínez, Leybis González González.

Elementa would like to thank Ana Rose Berbeo for translation from Spanish to English.

Funding information

Funding was provided by: Agencia Suiza para la Cooperación y el Desarrollo (Swiss Agency for Cooperation and Development, COSUDE), Cuba. CATIE, Costa Rica. Council of Churches of Cuba. ICRA, Holland. Higher Institute of

the Communist Party of Cuba, Small Donations Program. Global Environmental Fund. United Nations Development Program, Cuba.

Competing interests

The authors have no competing interests to declare.

Author contributions

- Contributed to conception and design: TMT, HMM, ASP
- Contributed to acquisition of data: TMT, HMM, ASP, LLL, KOC, JAAY, MAGN, IMCA
- Contributed to analysis and interpretation of data: TMT, HMM, ASP, LLL, KOC, JAAY, MAGN, IMCA
- Drafted and/or revised the article: TMT, HMM, ASP
- Approved the submitted version for publication: TMT, HMM

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How to cite this article: Miranda Tortoló, T, Machado Martínez, H, Suset Pérez, A, Lamela López, L, Oropesa Casanova, K, Alfonso Yanes, JA, García Naranjo, MA and Campos Acosta, IM. 2018. From technology transfer to innovation-based rural development: A necessary turn at the Indio Hatuey experimental station. *Elem Sci Anth*, **6**: 81. DOI: <https://doi.org/10.1525/elementa.325>

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Knowledge Domain: Sustainability Transitions

Part of an *Elementa* Special Feature: Cuba's Agrifood System in Transition

Submitted: 27 March 2017 **Accepted:** 12 October 2018 **Published:** 10 December 2018

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