Scientific Paper

Experiences of the Local Agricultural Innovation System to face productive challenges in the Perico municipality

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Abstract

The objective of the work was to show how the Local Agricultural Innovation System (SIAL, for its initials in Spanish) in the Perico municipality, Matanzas province, Cuba, was able to solve productive challenges from the moment they were detected in the Management Multi-Actor Platform (MMP), which started with the problem of low yield in the production of *Ipomoea batatas* (sweet potato) in the productive zone La Angelina. For such purpose different scientific methods and research techniques were used, such as: context diagnosis, surveys, soil sampling, among others. In addition, the results that were reached in the territory with the implementation of this type of approach in the different dimensions, were systematized; which allowed to perform several learning cycles and, in turn, have a plan of measures to increase sweet potato yields and improve the soil as fundamental and irreplaceable resource, capable of supporting crops and life in general.

Keywords: management, *Ipomoea batatas*, yield, soil

Introduction

The development of a nation depends on the acquisition of maturity to live from the available resources with independence. It is necessary to achieve this successfully in the entire territory, and this lies on the people who inhabit it, on their capacity of being, on their desire to change, on their confidence to undertake, definitely, to assume a protagonist role (Giménez, 2015).

For such reason, when local development is approached, it must be seen as a process that cannot exist unless it is within the framework of local autonomy, but it should be carried out by local actors, who accept the challenge of taking responsibility for their own destiny (Campos, 2012). In addition, this author in 2003 stated that the approach of local sustainable development necessarily implies the broad participation of human beings as active entities and main subjects of conservation.

In this sense, Cuba, as part of the implementation of the Guidelines of the Economic and Social Policy of the Cuban Communist Party and the Revolution (PCC, 2012), demands an improvement in the projection of higher education towards municipal local development. This purpose is in full agreement with the objectives of the project "Local Agricultural Innovation Program" (PIAL), led by the National Institute of Agricultural Sciences (INCA) and funded by the Swiss Development and Cooperation Agency (SDC). In the framework of this project actions have been developed in different municipalities from several Cuban provinces, in order to improve the women and men's quality of life, by enhancing the Participatory Local Agricultural Innovation Systems, the generation of genetic and technological diversity, as well as actors' articulation (Ortiz *et al*, 2017).

In the local development strategy of the Perico municipality, the main difficulties that hinder or deter the progress of the territory and, thus, those issues that must be approached in the short, medium-and long term, to satisfy the basic needs of the population, are identified. Among the main difficulties identified in the 2013-2020 Municipal Development Strategy (CAM, 2013), are: deterioration of agricultural production, with emphasis on the group of lands without adequate use and little diversity of agricultural production,

low offer of personal, technical and gastronomic services, low conservation level and ecosystem degradation (deforestation, soil compaction and fertility loss; biodiversity loss) and weak environmental education.

In order to solve these limitations and, especially, to articulate actors in the municipality, the PIAL project put into consideration of the government an alternative, result of their work experience: the creation of a Local Agricultural Innovation System (SIAL). This initiative does not wait passively for the farmers' development demands, but it rather incites and revitalizes them at mass scale, through the access to diversity in the leaning zones. Afterwards, it multiplies the innovative attitude and activity during its learning cycles and networks, and permanently attracts farmers and actors from the local agrifood chains (La O and Roselló, 2017).

In the Management Multi-Actor Platform (MMP) the challenge related to the decrease of the yield of sweet potato (*Ipomoea batatas* L.) was detected in the CCS José Martí of the town La Angelina, one of the largest productive centers of this tuber at national scale. Sweet potato is fundamental for the territory, because it constitutes the sixth food crop in order of importance worldwide (Rossel *et al*., 2014). In Cuba it is one of the most important staple crops for feeding the population; 47 617 ha are dedicated to its cultivation and its annual production is 517 618 tons approximately (ONEI, 2018). Due to its rustic nature, wide adaptability, short cycle, and to the fact that its planting material can be easily multiplied, sweet potato is planted throughout the year and in all the regions of the country (Rodríguez *et al*., 2017). In the Cuban context of agricultural production, crop management should include integrated nutritional programs, where nutritional compensation is implemented through organic amendments as part of sustainable agriculture, which allows to produce with the existing means in the productive sector (Simó *et al*., 2018).

The objective of this work was to show how the SIAL in the Perico municipality, Matanzas province, Cuba was capable of solving productive challenges, in this case from the problem of sweet potato production.

Materials and Methods

The SIAL consists in organizing locally the interrelation among the actors who participate in the functioning of agrifood chains, so that the limited available resources are destined to the study of the concrete needs of farmers and actors who integrate productive chains; the local knowledge of farmers and other actors is utilized to stimulate diversification and increase production sustainably. In addition, for the access of productive units and other chain actors to their peers' knowledge, generated in the territory by universities and research centers, to be facilitated (Ortiz *et al.,* 2017).

For such purpose it is necessary that two fundamental actors participate: Local Agricultural Innovation Groups (GIALs) and Management Multi-actor Platforms. The GIALs are constituted by farmers, representatives of Cooperatives of Credits and Services (CCSs), Cooperatives of Agricultural Production (CPAs), Basic Units of Cooperative Production (UBPCs), enterprises, the Urban and Suburban Agriculture Movement[1] or individual farmers, grouped depending on mutual interest to solve common challenges of their farms; while MMPs are led by the local government and have the facilitation of Municipal University Centers (CUMs), the National association of Small Farmers (ANAP) and/or other entities; they are in charge of coordinating and organizing, in the municipality, knowledge management, as well as promoting the creation and development of GIALs (Miranda *et al*., 2015; Labrador, 2017).

The MMP of the Perico territory was created in 2014, from the fusion with the Municipal Local Development Group, and enhances its functioning as implementation entity of the Municipal Integral Development Program (MIDP) and as managerial tool, to facilitate the effective conduction of the Municipal Government in the development programs, projects and strategies, in which it was proposed that for the first time farmers participated too.

This platform is led by the Municipal Administration Council (CAM), the first CAM vice-president and the CAM vice-president who supervises the food production sector. It is coordinated and facilitated by the official of this council who supervises the Municipal Integral Development Program,

[1] Urban agriculture. It is practiced in the inner contour of each village, town or city, and their periphery. In it the highest productions of vegetables in general are concentrated, with broad use of organoponic gardens, intensive, semi-protected vegetable gardens, home micro-gardens and suburban farms, with integral exploitation (agriculture, animal husbandry and forestry. (Rodríguez-Nodals, 2014).

along with the Municipal University and researchers from the Pastures and Forages Research Station Indio Hatuey (EEPFIH), and the project coordinators, who act as catalysts of the knowledge and innovation management process.

It is a space for the consolidation of strategic alliances to promote development in the municipality; it is an efficacious tool that favors team work and the elaboration of a common plan that is managed from the Government, which has allowed to modify the vertical direction styles by an orientation towards styles more aimed at the active and protagonist participation of local managers and the population (Miranda *et al*., 2018). This platform contributes to decision making from concrete proposals for the agreement between the MIDP and the projects that support its implementation, based on knowledge and innovation. It is made up as shown in figure 1.

The methodology described by Ortiz *et al*. (2017) was applied, as alternative to solve the low yield of sweet potato production (fig. 2).

This proposal is fundamentally based on four stages, which are described below:

Stage I. Diversity fair. Identification and generation of demands for development

The possibility that the decrease of sweet potato yields in the Cooperative of Credits and Services (CCS) José Martí of La Angelina (Primero de Mayo) town could be due to the low quality of the utilized biological material was considered and, for such reason, 20 clones from the National Institute of Tropical Food Crops (INIVIT) were obtained.

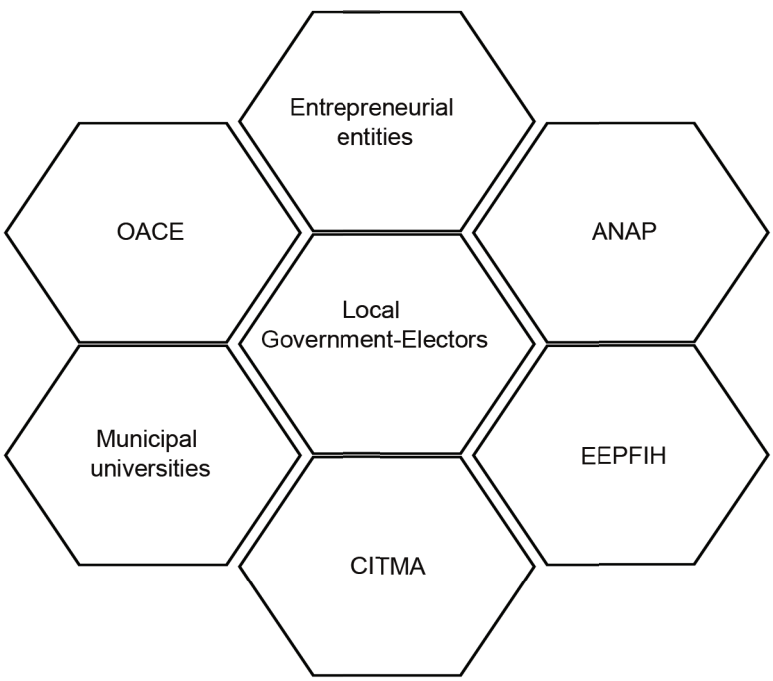


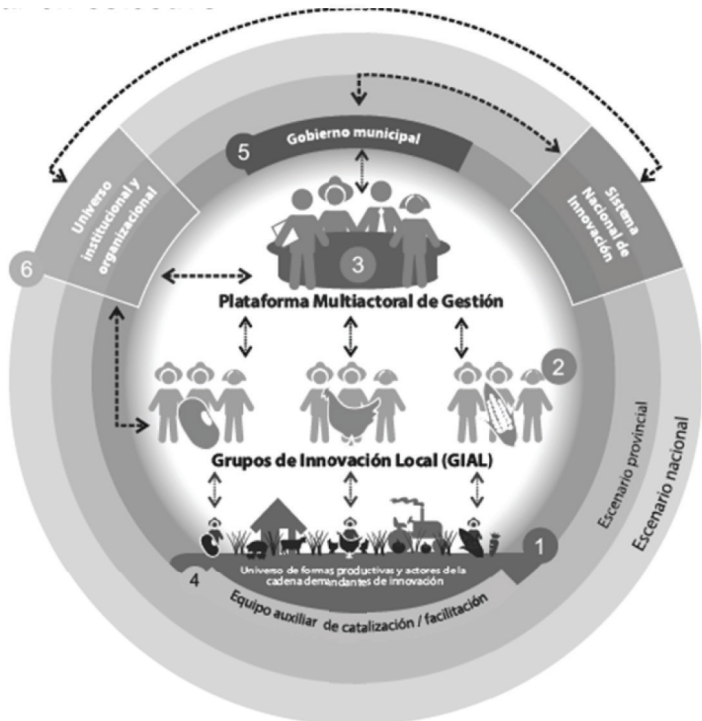
Figure 1. Figure 1. Network of actors who interact in the MMP. Elaborated by the author from García-Naranjo *et al.* (2015)

OACE: State Central Administration Organisms (Municipal Direction of Economy and Planning, Municipal Direction of Finances and Prices, Municipal Direction of Education, Municipal Direction of Culture, Municipal Direction of Public Health. Municipal Direction of Work and Social Security, Municipal Direction of Physical Planning (IPF), Municipal Direction of Communal Services, Municipal Direction of the National Statistics and Information Office (ONEI), Municipal Construction Direction of the People's Power and Municipal Delegation of Agriculture)

ANAP: Association of Small Farmers

CITMA: Ministry of Science, Technology and Environment

EEPFIH: Pastures and Forages Research Station Indio Hatuey



1- Universe of productive forms and chain actors who demand information.
2- Local Agricultural Innovation Group (GIAL).
3- Management Multi-Actor Platform (MMP).
4- Auxiliary catalyzing/facilitation team.
5- Municipal Government.
6- Institutional and organizational universe.

Figure 2. Diagram of the Local Agricultural Innovation System
Source: Ortiz (2016)

These clones were planted in the Cayo Piedra farm, belonging to farmer Fernando Donis, from that CCS, in order to carry out a diversity fair and for the leader farmers (7) in the production of this crop to choose the varieties they preferred, according to different selection criteria.

Stage II. Soil management. Social Innovation Organization

In this sense, the sweet potato GIAL was created with the leader farmers of this crop. The sweet potato clones obtained in the fair did not express their maximum yield in nine farms, and were below the historical mean. It was inferred, after an analysis in the GIAL, that the cause of the low yield could be the inadequate soil use and management.

To confirm this assumption, surveys were made with the GIAL members about the general characteristics of the studied farms, with emphasis on the utilization of agroecological practices which would allow to preserve or ameliorate the soil, as fundamental and irreplaceable resource; afterwards, the soil GIAL was created.

In addition, exchange was organized with the soil GIAL from Las Tunas province, due to their large experience in the work with this resource (Ray-Hayne, 2016; Estrada, 2016). For such purpose, other interested farmers, government actors and students from the polytechnic schools Fabricio Ojeda of the Perico municipality and Cesar Escalante of Jagüey Grande, as well as students of the scientific society from the municipal senior high school and from Agronomic Engineering of the University of Matanzas, were involved; who, from learning, were linked to concrete actions in order to transform the reality of the productive systems which were affected.

Stage III. Soil analysis. Collective action aimed by shared visions

After concluding the learning cycle related to the sweet potato variety, a new cycle related to the soil began to emerge. With the knowledge acquired in Las Tunas province during the exchange, a work

group was formed with the farmers, students and professors, managed from the MMP, with different purposes:

- To link farmers, students and professors to concrete tasks in the municipality.
- To relate the Soil subject of the Agronomic Engineering career with practical activities of the territory.
- To work in the vocational training of senior high school students
- To perform soil sampling in La Angelina farms.

The soil sampling in each area was carried out at a depth of 0-10 and 10-20 cm, through a zigzag scheme that comprised taking ten spots distributed throughout the length and width of the land. The soil samples in each stratum were separately homogenized, to obtain representative samples of 1 kg of weight approximately. The colorimetric method was used with the SMART3 colorimeter, to know the chemical characteristics of the soil.

Stage IV. Synergies. Socialization of results and process effects

A process of synergy was made with the project "Environmental Bases for Local Food Sustainability" (BASAL), through the MMP, because Perico is one of the scenarios in which this project participates. The soil was characterized and serious limitations for the tuber production were identified.

The BASAL project, within its objectives, attempts to reduce the vulnerabilities of the agricultural sector against the incidence of increasingly frequent and intense droughts , the increase of minimum air temperature (which propitiates the appearance of pests and diseases), as well as the rise of sea level, responsible for the salinization of underground waters and agricultural soil.

Results and Discussion

Stage I. Organization of a diversity fair

The diversity fair is considered a good mechanism to deliver to the producers of these agricultural systems the varieties of better performance than the ones they have traditionally used.

Cárdenas *et al.* (2016) proved that the diversity fairs provide high potentialities in the introduction, evaluation and participatory selection of foreign and national materials, in order to achieve increases in the diversity of cultivars of interest, better adapted to local conditions.

The GIAL integrated by seven sweet potato farmers of the CCS which had the problems with this crop, as well as other ones interested in acquiring new varieties, participated in the diversity fair. The agroecology coordinator and the facilitator of the ANAP in the municipality also took part.

In this sense, the farmers coincided on the fact that the indicators with higher bearing for the selection or rejection of the clones were yield and affectation by *Cylas formicarius*; 71,4 % preferred the variety IB-8 (table 1).

The selection of clone IB-8 coincides with the report by Ricardo (2007), who evaluated 14 sweet potato clones through participatory plant breeding, under the edaphoclimatic conditions of the Puerto Padre municipality, Las Tunas province. According to the farmers' criteria, the most widely selected clones were INIVIT B-24 and INIVIT B-8 with 30 and 21 %, respectively.

Stage II. Experiences in soil management

Figure 3 shows that the social object of 100 % of the farms was agricultural production; 80 % had more than 10 years of exploitation, and although the interviewees declared that the erosion degree was

Table 1. Relation of varieties chosen per farmer and selection criteria.

Variety	Farmer	Selection criterion
IB-1, IB-2, IB-3, IB-4, IB 2005, IB-5, IB-6, IB-7, IB-8, IB-9, IB-10, IB-12, IB-17, IB-23, IB-26, IB-61, C 78-354, IB 2005-2013, IB Morado, Local variety.	1 2	-Growth and leaf size -Number of tuberous roots -Yield -Resistance to *C. formicarius*
IB-8	3 4 5 6 7	-Yield -Growth and leaf size -Number of tuberous roots -Resistance to *C. formicarius*

Figure 3. General characteristics of the farms from the CCS José Martí.

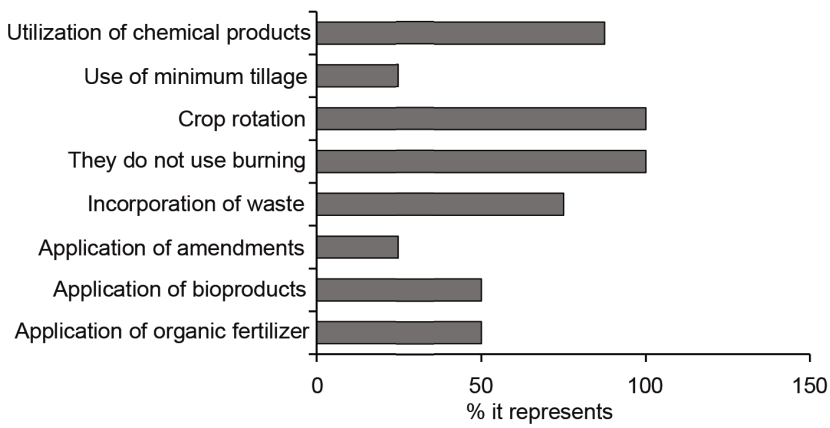


Figure 4. Percentage of agroecological practices used in the farms.

low, that is not what was perceived in the field. All the farms show flat topography, soils with sandy texture; while the presence of stones was not a limitation in these areas.

When analyzing the use of agroecological practices (fig. 4), as alternative for the system sustainability, the low use of amendments (22 %), little utilization of bioproducts (43 %) and organic fertilizers (40 %), as well as of minimum tillage (20 %), stand out; this could have contributed to the decrease of the soil fertility, according to the report by Leyva *et al.* (2017).

The utilization of bioproducts constitutes a priority for the development of Cuban agriculture in the search for new plant nutrition alternatives, in order to reduce the use of chemical fertilizers and supply mineral deficiencies in the soil.

Several studies state that the utilization of different bioproducts as a vital component of sustainable systems, constitutes an economically attractive and acceptable means to reduce external inputs, increase the quantity and quality of internal resources, besides being a good choice to improve the soil physical, chemical and biological characteristics (Becerra-de-Armas *et al*., 2014; João *et al*., 2016; Bécquer *et al*., 2019).

It is necessary to search for new environment-friendly fertilization alternatives, to decrease the continuous application of nitrogen fertilizers, which can cause negative impacts on the agroecosystems, such as nitrate leaching, contamination of water resources, and gas emissions, causing irreparable damage to the environment (Zahid *et al*., 2015) and potential risk for mankind (Vejan *et al*., 2016).

In general, the use of different agroecological practices constitutes an alternative that contributes to the sustainability of agroecosystems and the management of natural resources in rural zones (Fuentes and Marchant, 2016).

In turn, these agroecological practices maintain the plant cover as an effective measure of preserving water and soil, through the use of such practices as no tillage, mulch, cover crops and other appropriate methods. They provide a regular supply of organic matter (manure, compost and promotion of the soil activity and biology). They increase nutrient recycling mechanisms increase through rotation systems based on legumes and livestock integration, among others; and promote the regulation of pests with the increase of the biological activity of control agents, due to the introduction and/or conservation of natural enemies and antagonists.

Stage III. Soil analysis in farms belonging to farmers of La Angelina

The soil analysis of the farms produced the following information (table 2): the PO_4 contents remained high in all the entities, for which it was not a limiting factor; while K_2O, which is an essential element for crop growth, just like nitrogen, varied from moderate to high.

Rodríguez *et al*. (2019), when evaluating different concentrations of NPK and determining the most adequate nutritional solution for the growth and yield of sweet potato, obtained that the responses to the different combinations of N, P and K had an increasing trend, except with low doses of P (10 kg P_2O_5 ha^{-1}) and K (40 kg K_2O ha^{-1}). With all the P and K concentrations the response to N was positive, and higher with the moderate and high doses of the other two nutrients.

Likewise, Ngailo *et al*. (2013) also determined that the nitrogen excess favors to a large extent the development of the aerial part of the plant and damages the roots. For such reason, it is important to utilize not too much compost or manure, or not intercropping in all the rotations with legumes. The available nitrogen-potassium ratio is also important. There is a response to fertilization below 100 ppm of potassium and 1-2 ppm of phosphorus. Potassium is fundamental, because it thickens the roots from the transport of photoassimilates.

When analyzing the MG content, it was high only in the farms that belonged to farmers 1 and 2; while in the others it varied from 0 to low. The most important role of this element is being part of the chlorophyll molecule and decrease of the photosynthetic process. Magnesium is found as part of primary minerals such as ferromagnetic silicates, which are found in basic and ultrabasic igneous rocks. In Cuba, in serpentinite-supported soils no Mg deficiencies appear in spite of having acid pH

Table 2. Results of the soil analysis in seven farms.

Farmer	Depth	PO_4	Ammonia-nitrogen	Mg	K_2O	N_2O	NO_3	SO_4
1	0-10	High	Low	High	Moderate	Moderate-high	Moderate	0
	10-20	High	0	High	Moderate	High	Moderate	0
2	0-10	High	Low	High	High	Moderate-low	Moderate-high	Low
	10-20	High	Low	High	High	Moderate-high	Moderate-high	Low
3	0-10	High	Moderate	Moderate	Moderate	High	Moderate	Moderate
	10-20	High	Low	Moderate	High	High	High	Low
4	0-10	High	Moderate	0	High	Moderate	Moderate	0
	10-20	High	Moderate	0	High	0	Moderate	Low
5	0-10	High	Low	0	High	High	Moderate	Low
	10-20	High	0	0	Moderate	Moderate-high	0	Low
6	0-10	High	Low	Low	High	Moderate-high	Moderate	Low
	10-20	Low	Low	0	Moderate	Moderate-high	Moderate	Moderate-low
7	0-10	High	0	0	High	Moderate-high	Low	High
	10-20	High	Low	Moderate-low	High	Moderate-high	High	Low

(Ferritic and Fersialitic, ferromagnesian reddish Brown), which is not the case of the studied soil (Martín and Durán, 2011). In addition, according to these authors, the crops with higher magnesium needs are vegetables and fruit trees.

Stage IV. Synergy with other projects

According to the BASAL project, from the soil analysis in the La Angelina farm, a classification was made, which is described next: the soil is Typical Loam Humic, whose formation is determined by the accumulation of humus, hydromorphic and calcification conditions, aspects that are due to the deposit of loams that support this formation; occupy transition zones between drained lands and peaty swamps, are strongly humified in their top part, and in their lower part their show whitish color due to the mixture of fine carbonates with the clay.

This soil type shows, as main limiting factor, deficient general drainage conditions; it is regularly saturated by the increase of the aquifer, and flooding occurs in the dry season, which is stressed in the rainy season. The presence of an aquifer close to the surface is evident, situation that is apparently reinforced by the proximity of the El Roque canal. In some farms of the zone saline manifestations appear, which has to be duly studied (BASAL, 2015).

As response to the results of the soil study, the CCS José Martí outlined a plan of measures to improve the physical characteristics, and biological diversity in the soils, which is detailed below:

- To reforest 48 ha with fruit and timber trees for farm delimiting and for helping to decrease erosion by wind and water.
- To establish a soil conservation and amelioration plan.
- To apply measures in the movement of agroecological agriculture to 698 ha (sowing of green manures, utilization of harvest residues, application of organic matter, use of bioproducts, farm diversification, among others).
- To elaborate soil conservation project.
- To include the projects in FONADEF, related to soil biodiversity conservation and sustainable use.
- To promote the teaching of courses and workshops on soil biological diversity.

This plan of measures constitutes a fundamental tool for future projections of the CCS and of the municipality; in addition, it helps to solve the challenge detected in the MMP of the Perico government.

Final considerations

La Angelina, at present, has new sweet potato clones, with the soil chemical characterization, and a plan of measures for its amelioration and conservation, which will allow to increase the productive yields of sweet potato in the short term.

In addition, the government of Perico, from the MMP, is capable of detecting challenges, which are jointly solved, through learning in action cycles, in which the involved actors and catalysts participate.

SIAL, as methodology, turned out to be a tool that can be efficacious for the local governments to contribute to the management of their development strategies. It articulates farmers, representatives of governments, universities, research centers, institutional and non-institutional associations; which allows to stimulate municipal demands and actions that close cycles. It also helps the decentralization of their management, allowing to respond to the demands of the contexts where it is implemented and accompanied.

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