A co-innovation approach in family-farming livestock systems in Rocha - Uruguay: A three-year learning process

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Abstract: There are opportunities to improve livestock family farms (LFF) sustainability in Uruguay by changing management practices and incorporating technologies, using the co-innovation approach. To harness these opportunities, between 2012 and 2015 a research project was implemented in Eastern Uruguay, where three simultaneous processes occurred at three levels: farm, region and research team. At farm level, the work was carried out in seven LFF as case studies. Through monthly visits to the farms by a field agronomist the process followed three phases using the Evaluation of Natural Resource Management Systems Incorporating Sustainability Indicators (MESMIS) framework: (i) characterization and diagnosis, (ii) re-design, (iii) implementation, monitoring and evaluation. As a result, farmer knowledge and skills for farm management improved and the farms increased their meat production and net income (23 and 56% on average, respectively) while preserving natural resources. At regional level, a participatory approach to planning, monitoring and evaluating the project´s progress with regional stakeholders was adapted from a Participatory Analysis of Impact Pathways (PIPA) method. An interinstitutional network was consolidated, which developed a common vision and expected project outcomes and designed a communication plan to disseminate the results. At team level, a Participatory Action Research (PAR) approach was carried out. A transdisciplinary team was consolidated through cyclic processes of research, reflection and action. Consensus on the objectives and methods allowed combining knowledge to solve practice-oriented problems. The three-year process demonstrated effectiveness in improving LFF sustainability, opening a learning space with stakeholders and contributing with a novel model of rural development: co-innovation.

Keywords: Methodology, MESMIS, PAR, PIPA, Systemic Approach, Monitoring and Evaluation, Co-innovation

1. Introduction

During the last decade: 21% of the farms disappeared in Uruguay between 2000 and 2011 (Cortelezzi and Mondelli, 2014). Nowadays, there are more than 26,000 livestock farms covering more than 11.7 million hectares, most of which (60%) are family farms (Tommasino *et al*., 2014). In our work, and according to the definition of family-farming provided by the Uruguayan Ministry of Livestock and Agriculture, "family-farming" satisfies the following criteria: labour is mainly provided by the family while hired labour is limited, the family is directly responsible for the production and management of agricultural activities, the family lives on the farm or within a 50 km radius, and the production is intended for self consumption and marketing (Tommasino *et al*., 2014).

The traditional model of agricultural technology transfer has led to low adoption of improved agricultural technologies (Moschitz *et al.,* 2015; Okali *et al.*, 1994). On the other hand, the active participation of the farmers in the process of problem identification and development of alternatives may maximize the impact of the generated proposals (Leeuwis and Van der Ban, 2004). Accordingly, some advances have been observed in Uruguay by the National Agricultural Research Institute (INIA*)* while working together with organic farmers (Albicette, 2011), and by the Faculty of Agronomy of the University of the Republic with livestock and horticultural farmers (Dogliotti *et al*., 2012; 2014). This presupposes a research process paradigm shift, where the human factor is an integral part of the innovation process.

Most of the livestock family farms (LFF) in Uruguay apply low technology levels and consequently they present low production efficiency with substantial fluctuations between years (Pereira, 2003). At farm level, some opportunities can be identified to improve family-farm production efficiency and sustainability through an adequate selection and orientation of production activities and the use of appropriate technology and farming management skills. In line with this, technical information for natural grassland management (Soca *et al*., 2013; Altesor *et al*., 2011) and cattle and sheep management (Nabinger *et al*., 2011; Quintans and Scarsi, 2013) is available and known by end users. Farm sustainability cannot be solved by mere adjustments or modifications in isolated components of the system, which generally responds to disciplinary advances. To improve LFF sustainability, a systemic approach of LFF is needed, therefore implying changes in the quality and availability of production resources, along with changes in farm management. The latter includes certain changes in knowledge, skills, attitudes and abilities - KASA (Rockwell and Bennett, 2004) of the family (Dogliotti *et al*., 2012; 2014). A Rapid Rural Appraisal (RRA) (Schönhuth and Kievelitz, 1994) was conducted during 2009 and 2010 in Rocha, Eastern Uruguay by INIA in collaboration with local farmer organizations (Sociedad de Fomento Rural-Ruta 109 - SFR-R109, Sociedad de Fomento Rural-Castillos - SFR-C), the national farmer union (Comisión Nacional de Fomento Rural - CNFR) and local government (Intendencia Municipal de Rocha - IMR). Through this RRA we confirmed a reduction of the number of family farms and an increase of average farmer´s age. We also identified knowledge gaps and misuse of the available technological alternatives related to low income. As a consequence, the strategy of the farmers was to intensify their production (i.e. use of external sources of feed, substituting natural grasslands by sowed pastures, increases in animal stocking rate), usually associated with inadequate technologies and practices. This posed a risk to natural resource preservation while affecting the present productivity and compromising sustainability for future generations (Capra *et al*., 2009).

The project "Co-innovating for the sustainable development of family-farming systems in Rocha-Uruguay" aimed to contribute, from the scientific research and the technological development standpoint, to the improvement of family-farming systems sustainability, the development of this rural area, and the improvement of farmer wellbeing using a co-innovation process. As defined by Coutts *et al.* (2014), co-innovation is a participative and interactive approach to fostering effective innovation across sectors and stakeholders. Within this project we proposed a methodological framework to design, implement, monitor and evaluate (M&E) an intervention strategy for improving LFF sustainability.

2. Materials and Methods

We implemented a co-innovation approach that combines complex systems theory, social learning and dynamic project M&E (Rossing *et al*., 2010) at three interconnected and simultaneous levels: farm, region and research team (Figure 1). The process occurred over three years (2012-2015) and involved two rural areas of Rocha - Uruguay: Castillos on the one hand and the hilly areas delimited by 109 and 15 Roads on the other hand (Figure 2).

Figure 1. Project methodological approach. The co-innovation approach was implemented at three simultaneous and interconnected levels: farm, region and research team. At each level specific methods/methodologies were used and supported the diagnosis, re-design and implementation, monitoring and evaluation of the introduced changes in the farming systems. [1] MESMIS: Framework for the Evaluation of Natural Resource Management Systems Incorporating Sustainability Indicators (Masera *et al*., 2000); [2] PIPA: Participatory Impact Pathways Analysis (Alvarez *et al*., 2010); [3] PAR: Participatory Action Research (Moschitz and Home, 2014**).**

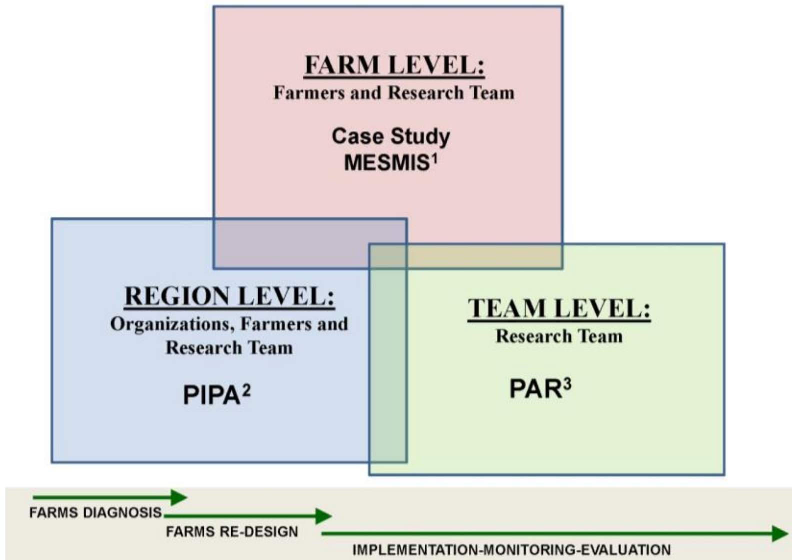


Figure 2. Localization of the rural areas where the project was implemented: Castillos and Rocha hilly area, Rocha –Uruguay.

2.1. Farm level

To improve LFF sustainability, we implemented a multiple case study (Yin, 2014) within the MESMIS framework (Spanish acronym for Evaluation of Natural Resource Management Systems Incorporating Sustainability Indicators [Masera *et al*., 2000]). Seven family farms were selected jointly by INIA researchers, extension agents of two grassroots local farmer organizations (SFR-R109 and SFR-C) and agronomists of the national farmer union (CNFR). The main activity of the selected LFF is livestock production (raising cattle and sheep) based on native grasslands.

Three phases according to Dogliotti *et al.* (2014) were followed: (i) characterization and diagnosis, (ii) re-design of the farming system, (iii) implementation and M&E of the proposed changes in the farming system. The field agronomist was responsible for supporting the farmer and the family to implement the proposed changes as well as monitoring the whole process. To perform this, the field agronomist visited each farm on a monthly basis. He also facilitated the connection between the farmers and the research team members responsible for collecting on-farm information regarding grassland and animal management, environmental indicators, and social processes.

The **characterization and diagnosis** at each LFF was undertaken by the farmer and his family along with the field agronomist and the research team. The status and operation of the production systems were described, and the main problems of these systems were identified taking into account the family´s conception of sustainability. Finally, based on the MESMIS framework (Masera *et al*., 2000) the critical points were organized according to four groups of sustainable attributes (productivity, stability, reliability-adaptability-resilience, self-reliance) and the indicators to monitor them were determined (Table 1). During the **re-design** phase (strategic planning) of the LFF, different productive alternatives were proposed based on the resources available on the farm. After that, the proposals were evaluated by quantifying the expected physical and economic results, as well as the potential impact on farm management and on natural resources. After a learning process where the producer's practical knowledge and the scientific knowledge provided by the research team merged jointly, one proposal was constructed by the family and the field agronomist in order to overcome the critical points. The last phase of the process was the **implementation** (tactical planning) and **M&E of the proposal**. The impact of the re-designed system was monitored and quantified with the selected indicators. As the process evolved, some unexpected difficulties arose, and thus the original proposal was adjusted through continuous cycles of re-design and implementation.

2.2. Region level

The Participatory Analysis of Impact Pathways (PIPA) was designed to help the people involved in a project to explicitly present their expectations towards the project, and to plan, implement and monitor activities together in order to fulfil those expectations (Alvarez *et al.,* 2010). In our case, we used PIPA to support and disseminate the processes which took place at farm level, therefore we engaged regional stakeholders in a participatory learning process during interinstitutional workshops carried out twice a year. During these workshops participatory methods were selected among a toolkit (Knowledge Sharing Toolkit, 2009; UNICEF Bangladesh, 1993) and a facilitator guided the discussions and the reflection process. To keep continuity along the process, workshops activities were documented and systematized in minutes, and sent to each participant to be used as memory refreshers and starting points for the succeeding meetings. As the project advanced and changes occurred, lessons learned were incorporated in real time. In the last workshop, a written survey was conducted to evaluate the project performance and outcomes, both qualitatively and quantitatively. This survey was composed of 17 questions regarding global assessment, goals achievement, project performance, other topics and future impact of results, on a Likert scale ranging from 1 = very bad to 5 = excellent.

2.3. Team level

A multidisciplinary team (research team) was set up to elaborate and implement the project, to conduct M&E of the processes at farm and region levels, and to answer specific research questions. The research team followed a Participatory Action Research (PAR) process. PAR presupposes a cyclic process of research, reflection and action where the researchers are both participants and learners (MacDonald, 2012). The research team held a varied range of backgrounds and expertise, for example: farm management, pasture and grassland management, livestock production, soil sciences, environmental impact assessment and social sciences.

Two one-day workshops per year were organized aiming to achieve a common vision of the objective and methodology of the project, plan activities, reflect on the process and discuss partial results and how to communicate them. In these workshops participatory methods were implemented as previously described in the Region level section.

Finally, to evaluate the process within the team, we implemented a quantitative survey designed to evaluate transdisciplinary research (Small *et al*., 2015). The survey consisted of 38 questions/statements accounting for the key process factors in transdisciplinarity, to be scored within a 1 to 7 scale (1 = very poor to 7 = very good) and included the possibility of adding comments regarding the addressed issue. Complementary, researchers were asked to provide up to three lessons learned from the project. The survey was delivered by e-mail to the researchers and was anonymously answered.

3. Results

3.1. Farm level

During the first year (2012) each farm was characterized and the main weaknesses and strengths were organized into sustainability attributes and critical points according to MESMIS (Table 1). Among the weaknesses the following were identified: (i) low productivity associated with low family income and labour organization, (ii) low use of improved technologies for animal, grassland and farm management, and (iii) degraded natural resources, mainly native pastures and soil. On the other hand, the strengths were: (i) high degree of satisfaction with their livelihood and availability of family labour, and (ii) high biodiversity.

Considering the previous analysis, the second phase –re-design of the farming system– took place over the course of two years (2013-2014). Several proposals were elaborated for each farm, and those which did not imply any incremental costs and use the on-farm resources were selected. After reaching an agreement on the production objectives, the proposals focused on: (i) adjustments to the system´s stocking rate (total stocking rate and bovine/ovine ratio), (ii) use and application of technologies for cow-calf systems, (iii) grazing management using different paddocks according to pasture height and animal age.

Table 1. Main critical points and indicators used to assess livestock family farms (LFF) performance, organized in four groups of sustainability attributes and sustainability dimensions, according to MESMIS.

Sustainability attribute	Critical point	Indicator (unit/scale)	Sustainability dimension
Productivity	Low productivity	Equivalent meat production [1] (kg ha^{-1} $year^{-1}$)	Economic
	Low family income	Net income (US$ ha^{-1} $year^{-1}$)	Economic
Stability	High level of satisfaction with family livelihood	Subjective life quality [2]	Social
	Low labour organization	Workload on animals and pasture management (h $year^{-1}$)	Social
	Low use of improved technologies	Implemented improved technology (%)[3]	Social
	High biodiversity	Birds Richness [4] and Birds diversity (Shannon Index=H) [5]	Environmental
	Degraded natural grasslands	Spring biomass of native grassland (kg DM ha^{-1})	Environmental
Reliability/ Adaptability/ Resiliency	Degraded soils	Labile organic carbon (mg C. kg $soil^{-1}$)	Environmental
	Availability of family labour	Proportion of workload provided by the family on animals and pasture management (%)	Social
Self-reliance	Low farm management skills	Mid and long term planning [6]	Social

[1] Equivalent meat production ha^{-1} = (kg meat + 2.48*kg wool)/grazing area; [2] According to family perception, from 5 = very satisfied to 1 = not satisfied; [3] Proposed production technologies: 100% means common 11 technologies proposed to all farmers for the re-design of the LFF (e.g.: adjustment in stocking rate, animal allocation according pasture biomass pregnancy diagnosis); [4] Number of species; [5] Shannon Index $H= -\Sigma\, p_i \ln p_i$, where p = the proportion of species, r = total of species, and *i* varies from 1 to r; [6] Scale from 5 = value and apply long-term planning to 1 = not value and do not apply planning.

The implementation of the proposals for the re-design of LFFs started in 2013. Over a period of two years, the impacts of the introduced changes were monitored by using a set of indicators accounting for the three dimensions of sustainability (Table 1). As for the economic dimension, the seven farms increased average equivalent meat production from 99 to 123 kg ha^{-1} $year^{-1}$ and their net income from 58 to 98 US$ ha^{-1} $year^{-1}$. Regarding the environmental dimension, the amount of standing spring biomass of natural grasslands increased from 1183 to 1868 kg DM ha^{-1}, while the diversity of birds as well as the labile organic carbon fraction of soils (760 mg C. kg $soil^{-1}$) were maintained in this environment. Finally, significant changes in the social dimension were observed: 25% reduction in workload on animals and pasture management, the use of the 11 proposed technologies increased from 39 to 97 %, and farmers shifted from "not planning" to starting "mid-term planning". All of these advances were a result of changes in farmers´ knowledge and skills on how to understand and manage their LFFs, as expressed by themselves: "*we now know how to manage pastures and cattle", "with less we can do things in a better way", "now we have more clear production objectives, we know when to do things"*.

3.2. Region level

An interinstitutional network of several actors in relation to rural development was generated. The actors were the seven above mentioned families, the research team and representatives of the farmer organizations and union (SFR-C, SFR-R109 and CNFR), the University, local and national government, and local extension services (Albicette *et al*., 2016).

During the first interinstitutional workshop participants developed a shared view of what their expectations were at the end of the project (the vision) regarding: (i) contribution to enhancing sustainability of the farms in the region, (ii) improvement of interactions among farmers, (iii) promotion of knowledge acquisition and development of abilities for farm management, (iv) increasing networking towards LFF development, (v) dissemination of the acquired knowledge through field days and mass media. The participants discussed the impact of several pathways and proposed strategies, outputs and outcomes to achieve that vision. A communication plan (CP) for the project was elaborated considering its strategy. During the following PIPA workshops the research team members shared the implemented project´s activities and obtained results thus anyone could follow the process. Participants reflected upon results and progresses achieved so far considering the elaborated strategy, using participatory methods and suggested changes for better impacts. This was seen as the M&E process of the PIPA. Activities and workshop results were documented in minutes, which were used for linking the workshops together.

The CP aimed to effectively disseminate project results and promote learning considering different objectives groups: farmers, professionals involved in rural development and organizations. As an example, we present the strategy plan for farmers (Figure 3) and for professionals involved in rural development (Figure 4). Specific activities were defined annually during PIPA workshops.

Figure 3. Communication strategy for farmers

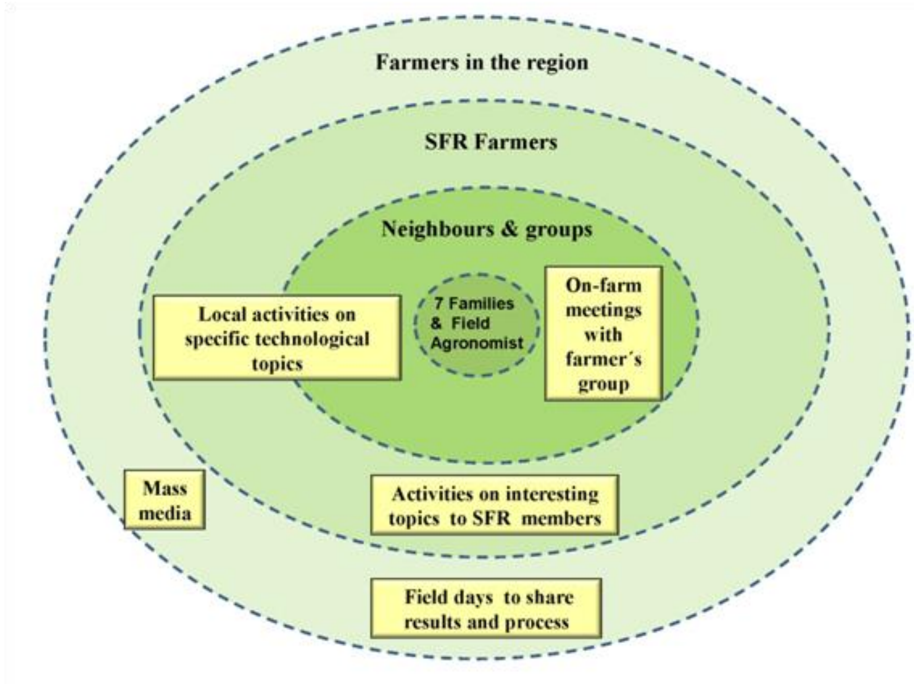
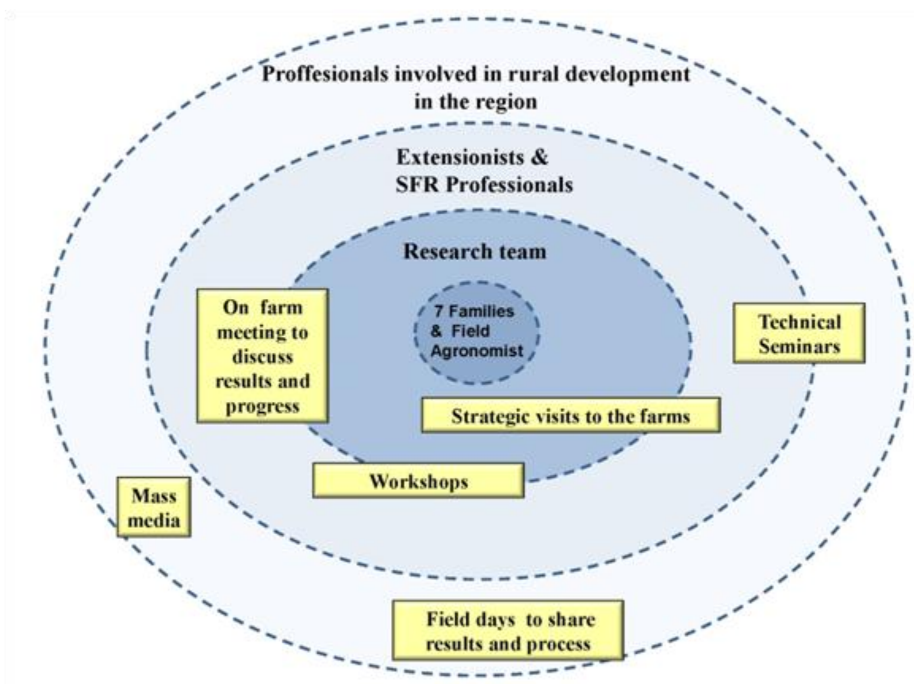


Figure 4. Communication strategy for professionals involved in rural development



During 2014 and 2016 several activities according to the designed plan took place. Five field days were organized and supported by the interinstitutional network, involving more than 600 participants. In December 2015 almost 200 people participated in the final field day where the research team, farmers and members of the interinstitutional network exchanged results and lessons learned with the participants. The evaluation of the activity was answered by 98 persons, where 65% were farmers. The field day was scored as very good or excellent by 93% of the responses and 83% considered that the technological proposals were useful for the farm to which each worked. At the end of the field day, a session with members of national organizations reflected on the project's results and exchanged ideas for the future of Uruguayan LFF[1]. In that opportunity the Rural Development Director of Ministry of Livestock stated that the results of this project had shown that in LFFs it is possible to undertake an intensification process along with increasing sustainability and adapting to climate change. Furthermore, he expressed: "*This is not a minor result: with this rigorous scientific data the country's productivity and the competitiveness of livestock family production could be improved*". Complementary, the representative of CNFR said: "*We valued this way of working and we are looking forward to reaching out to more farmers. Fifteen days ago, we presented a project based on this methodology, which will allow us to obtain funding to reach other regions and farmers".*

The final evaluation of the three-year process was answered by 18 stakeholders (excluding INIA participants), in which all were asked to score certain project related issues. The global project was valued as "very good" with a mean value of 4.22 out of 5. The relevance of the changes occurred on the seven farms was valued 4.28. Two main topics were highly valued, the methodology used to work with farmers (4.44) and the incorporation of suggestion during the project (4.17). The less valued topics were related to the information available in the region of the project results (3.61) and the impact of these results on the near future (3.4).

3.3. Team level

We consolidated a research team with 25 members including 17 researchers and 8 assistants. A PAR methodology advanced our understanding of the progresses in different areas (economic-productive, environmental and social), guided from the beginning by different disciplinary researchers. It took six workshops of the whole research team to understand the research problem, as well as the methodological approach, and several interdisciplinary meetings for discussions guiding the research process. As the process advanced, the workshops focused on analyzing the strengths and weaknesses of the project´s implementation, which allowed for the incorporation of lessons learned during the project.

Transdisciplinarity emerged as a new property of the project team integrated by researchers, farmers and local actors. Transdisciplinarity was validated through a survey implemented according to Small *et al.* (2015), where process success factors were valued as positive with an average score of 5.40 of a maximum of 7.00. The survey was anonymously answered by 21 members of the research team in 2015.

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[1] For more information about the 2015´s field day: http://www.inia.uy/estaciones-experimentales/direcciones-regionales/inia-treinta-y-tres/hacia-una-ganader%C3%ADa-familiar-sustentable-jornada-final-del-proyecto-co-innovando-en-rocha-2012-%E2%80%93-2015

4. Discussion and final considerations

To develop sustainable agricultural practices researchers need to collaborate with end-users of technology (Akpo *et al*., 2015; Dogliotti *et al*., 2012). Consequently, joint definitions of problems and opportunities among the seven farmers and the research team, and considering family's needs and resources, were key elements in the development of the ongoing re-design of proposals. The results at farm level showed that all the farms improved sustainability, evaluated through a combination of several indicators (Table 1), with the MESMIS method including social quantitative indicators, as Astier *et al.* (2011) point out. Learning occurred based on the data obtained from the indicators that were measured and analyzed. Some economic and environmental indicators were reaffirmed in its importance, and new social indicators were designed and used to better understand changes and learning processes in family farming systems (Astier *et al*., 2011).

Changes on farm took place thanks to the co-working between farmers and the research team, especially the field agronomist, mixing their knowledge of farming systems and learning together. A strong relationship between them generated confidence and trust (Rossi, 2011) as well as contributing to the rapid response of farmers to understand the use of technology, improving their knowledge, abilities and skills (Rockwell and Bennett, 2004) and finally innovating on their farms (Klerkx *et al*., 2012). Furthermore, they all have new aspirations of deepening the process of improving farm sustainability. As mentioned by Drechsel *et al.* (2001) changes in KASA are a prerequisite for the adoption of an innovation if other conditions are favorable.

Local actors were involved in a three-year project process, considering the seven farms and generating an interinstitutional network that was capable of designing a common vision of what was expected from the project, as well as the planning to make changes happen (Alvarez *et al*., 2010). The communication plan elaborated by the network defined activities that helped to disseminate the experience, contributed to local development. The vision, the project´s strategies and the activities had been changed during the process to some extent, based on the M&E process and on what had been learned (Douthwaite *et al.,* 2003). The participatory process continued as an experiential learning cycle that can be compared with that described by Douthwaite *et al.* (2002). The more remarkable results considering the regional level were: (i) government and policy makers now know about the project strategy and results and considered it as an inspiring approach towards implementation of LFF policies (ii) key organizations related to rural development as CNFR are now using this methodology in their development projects with farmers. Considering all that, the project directly contributed to enhance LFF sustainability and rural development.

The PAR methodology (Moschitz and Home, 2014) used by the research team resulted in a novel way of addressing agricultural complex problems by INIA. Furthermore, transdisciplinarity can be seen as a new avenue for generating knowledge along with farmers, representing an institutional innovation (Klerkx *et al*., 2012; Moschitz and Home, 2014). This approach challenges the research institutions in order to face practice oriented problems, demanding further development and adaptation according to the needs of other research teams.

Finally, the process of changing toward more sustainable LFF systems in Rocha-Uruguay was achieved by applying a co-innovation approach (Rossing *et al*., 2010). A three-year learning process jointly implemented by farmers, researchers and interinstitutional network members was based on: (i) working with a systemic view aimed at solving real problems felt by farmers, (ii) combining three levels of action: farm, region and team, (iii) considering an adequate period of time to allow changes and their assessment, (iv) M&E of the process encouraging a learning process among stakeholders, (vi) and allowing flexibility to incorporate lessons learned and to make adjustments during the project. The results presented in this work demonstrate that the approach used to address complex systemic challenges and to solve practice-oriented problems using/applying participatory approaches/methods was effective to enhance LFF sustainability and to contribute to rural development, albeit at small scale. However, this is an ongoing learning process that needs to continue and improve.

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