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Social-Ecological System Transformation and Learning: the case of Santa Rosa de Lima's dairy system, Brazil

Andréa Castelo Branco Brasileiro-Assing [I]
Claudia Sattler [II]
Barbara Schröter [II, III]
Juan P. Alvez [IV]
Paulo Antônio de Almeida Sinisgalli [V]
Abdon Schmitt Filho [VI]

[I] *University of São Paulo, Graduate Program on Environmental Science. Santa Rosa de Lima, Santa Catarina, Brasil.*

[II] *Leibniz Centre for Agricultural Landscape Research (ZALF), Working group: "Governance of Ecosystem Services". Müncheberg, Brandemburgo, Germany.*

[III] *Lund University, Centre for Sustainability Studies (LUCSUS), Lund, Sweden*

[IV] *University of Vermont Extension, Center for Sustainable Agriculture. Burlington, Vermont, United States of America.*

[V] *University of São Paulo, Graduate Program on Environmental Science. São Paulo, São Paulo, Brasil.*

[VI] *Silvopastoril Systems and Ecological Restoration Lab (LASSre), Agroecosystem Program at University of Santa Catarina (PGA/UFSC). Florianópolis, Santa Catarina, Brasil.*

Abstract: Conventional pastureland management has brought Southern Brazilian dairy farms to a financial and environmental crisis. In this context, the management-intensive grazing system (MIG) emerges as a viable alternative to conventional pastureland management. This study aims to analyze the Social-Ecological System (SES) transformation process of the dairy system in Santa Rosa de Lima, Southern Brazil, from conventional management to MIG. For the analysis, two different frameworks were combined: SES transformation process and the triple-loop learning frameworks. The analysis was based on a statistical analysis of interviews, conducted with dairy farmers. Results show that the dairy system in Santa Rosa de Lima is in the middle of a transformation process. During this phase, farmers have already reached single and, partially, double-loop learning. Among the elements needed to successfully move the transformation process forward, social learning stands out as indispensable, as well as financial capital. For this, payments for ecosystem services are suggested.

Keywords: Social-ecological systems; transformation; family dairy system; triple-loop learning; social capital.

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1. INTRODUCTION

Continuously grazed pastures or extensive grazing and semi-confinement based on corn silage has led the southern Brazilian dairy farms to financial and environmental crisis, compromising their integrity (RUVIARO, et al. 2020; BRASILEIRO – ASSING, 2018; CARDOSO et al., 2016; DICK; SILVA; DEWES; 2015). Grazing ecosystems provide ecosystem services, including food, and also depend on supporting ecosystem services, such as nutrient and water cycling,to keep their functionality.

Bustamante et al. (2012) estimated that 75% of forest conversion in Brazil may be associated with cattle ranching. According to the Brazilian Institute of Geography and Statistics (IBGE), in 2017, pastureland covers about 19% of Brazilian area. In 2018, 2.6 million hectares were newly converted to pasture. Thereof, 91% were converted from natural areas, or areas made up of mosaics including natural areas (IBGE, 2018). Furthermore, Primavesi et al. (2015), cited by Ruviaro (2020), states that: "the most common milk production in Brazil is through continuous grazing. Only 2.4% of the milk produced in the country comes from intensively confinement systems". Continuous grazing has caused overgrazing, which lead to above and below ground biodiversity and fertility loss, erosion, lower infiltration rates, and higher nutrient runoff (SUTTIE; REYNOLDS; SABATELLO, 2005).

In response to advanced economic and environmental crisis due to extensively grazed pasture and corn silage planted conventionally, the Santa Rosa de Lima municipality (SRL), in Santa Catarina State, Brazil, has introduced the Management Intensive Grazing System (MIG) as a sustainable alternative to replace conventional, extensive and area-demanding dairy system. MIG is based on agroecological principles and help farmers to reconcile economic and livelihood interests with agroecosystem restoration (JANZEN, 2011; TEAGUE et al., 2011). In MIG, high-stock density animals are rotated through paddocks for a period of one to three days each, while the remainder pastures are allowed to rest and recover, avoiding overgrazing, and respecting the different nutritional requirements of the animals (VOISIN, 1988).

Against this backdrop, this study aims to analyze the social-ecological system transformation process of SRL's dairy system and the associated effects on social learning, since the success of the transformation processes will strongly depend on the collective change of farmers' underlying values and beliefs. The theorists of the social-ecological system transformation mention several factors as relevant to make the transformation happen, which, besides values and beliefs, includes financial incentives (HILBORN et al., 2005; GUTIERREZ et al., 2011), transaction costs (ADHIKARI; LOVETT, 2006; MARSHALL, 2013), eco-labelling (THRANE et al., 2009), and government regulations (MOORE et al., 2014). This research focuses on values and beliefs as they are two of the key elements of social-ecological system transformation (MOORE et al, 2014) and because of their influence on intentional transformations, which constitutes our hypothesis for what occurs in this case study. Therefore, our research addresses the following research questions: (a) What is the status of the social-ecological system transformation of Santa Rosa de Lima's dairy system? (b) What are the learning effects during the transformation process? In order to answer these questions, the framework for social-ecological system transformation developed by Moore et al. (2014) was combined with the triple-loop learning framework developed by Pahl-Wostl (2009). Both approaches are presented next.

2. ANALYTICAL FRAMEWORK DEVELOPMENT

2.1 FRAMEWORK ON SOCIAL-ECOLOGICAL SYSTEM TRANSFORMATION

The Social-Ecological System (SES) approach frames "relationships between human and ecological components as part of a complex system with multi-scale feedbacks and dependencies" (VIRAPONGSE et al., 2016, p. 84). If the conditions of these relationships are compromised, a process of adaptation is required. If the adaptation is reached successfully, the system shows resilience to these stresses. However, if the system does not adapt to the new conditions, it shows loss of resilience and need for transformation (LYON, 2014).

The current dairy system in SRL, just like many other agri-food systems in the global context, has faced an extensive environmental, political, economic, and financial crisis (GLIESSMAN, 2014). Additionally, its resilience has been shown to be low (SCHMITT FILHO; MURPHY; FARLEY, 2010; LYON, 2014). Thus, a transformation towards a more suitable SES based on social structural changes is needed.

Moore et al. (2014) presents a framework to analyze and plan a SES transformation process (Table 1). The framework comprise four phases, including the respective sub-processes for each phase.

Table 1 - Framework for analyzing the multiple sub-processes in each phase of a social-ecological system transformation process

Phases	Sub-processes	Description
Triggers or Pre-transformation		Mostly characterized by social or ecological disruptions, which consequently create windows of opportunity.
Preparing for change	**Sensemaking**	Investigating structures that are problematic for current trajectory.
	Envisioning	Creating new innovations and visions for the future
	Gathering momentum	Self-organization around new ideas, including the creation and mobilization of networks of support, and experimentation in pilot projects.

Navigating the transition	**Selecting**	Selecting which innovation or change process in which to invest social, intellectual, and financial capital.
	Learning	Assessing the results of earlier experiments and developing shared understandings or new forms of knowledge.
	Adoption	Widespread uptake or reproduction of innovative change that was successful in experimental stage.
Institutionalizing the new trajectory	**Routinization**	Handling dynamic stability to embed new trajectory and establish or strengthen new feedbacks.
	Strengthening cross-scale relationship	Scaling up the change, which often involves a different type of innovation than was created originally in pilot projects.
	Stabilization	Dealing with next, unanticipated perturbations, since resistance from powerful actors at different scales is likely.

Source: adapted after Moore et al. (2014)

The framework explicitly shows what can be expected to change and how the processes underpinning that change will unfold during the transformation.

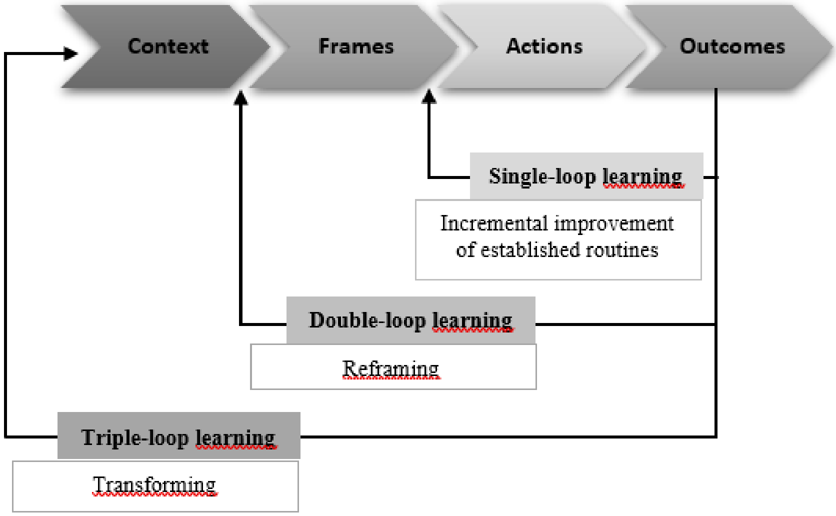
2.2 FRAMEWORK ON SOCIAL LEARNING

Social learning can be defined as a process of social change in which the communication and interaction of different actors are required in a participatory setting to promote social outcomes to form the basis for a common understanding, agreement and collective action (MURO; JEFFREY, 2008).

Pahl-Wostl (2002) presents an approach based on the assumption of feedback loops (see **Figure 1**), which result from transformative learning, where people gradually change their views on the world and themselves (ARGYRIS; SCHÖN, 1978). As a process, social learning encompasses three levels: single, double and triple-loop learning. Single-loop learning refers to "an incremental of action without questioning the underlying assumption" (PAHL-WOSTL, 2009, p. 359). The performance of the existing system is improved, only within the traditional routines, but taking into consideration collective decision-making. Double-loop learning includes reflecting on actions and assumptions within a value-normative framework. Here, actors reframe their problems and goals and experiment with new approaches. Finally, triple-loop learning means reconsidering underlying values and beliefs, world views, therefore promoting a transformation of the structural context and factors that determine the frame of reference (ARGYRIS; SCHÖN, 1978; FAZEY;

FAZEY; FAZEY, 2005; TOSEY; VISSER; SAUNDERS, 2012).

Figure 1 - Sequence of learning cycles in the concept of triple-loop learning



Source: slightly adapted after Pahl-Wostl (2009).

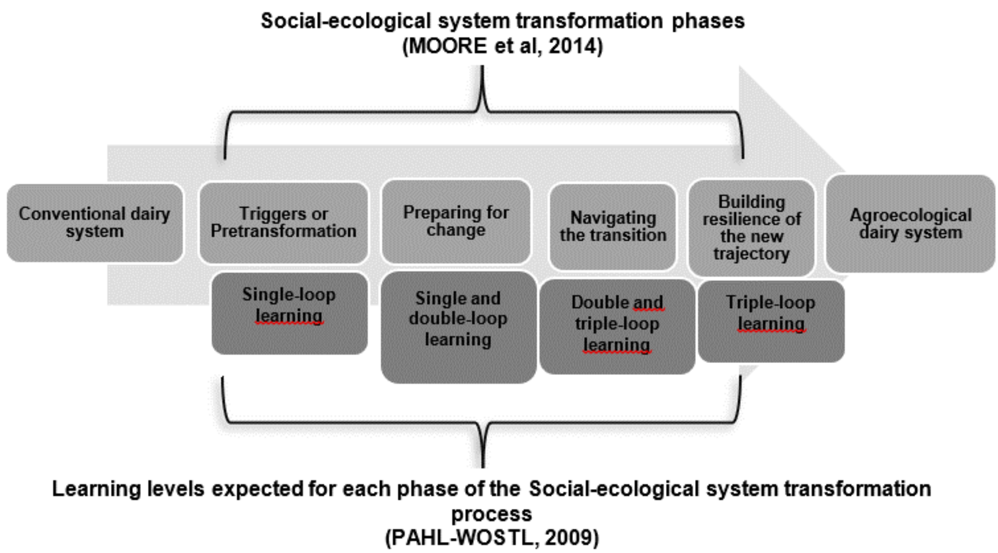
Single, double, and triple loop learning underpin the transformation, which is a form of change that recombines existing elements of a system in fundamentally novel ways (MOORE et al., 2014).

The initial process of social learning seems natural, since the disruption of a system requires urgently new actions to maintain its functioning. However, the ongoing process of social learning that promotes structural change demands social engagement and transfer of knowledge. Muro and Jeffrey (2008, p. 326) mention that for the process of learning to happen in the first place, the establishment of "participatory learning environments and platforms" are needed, "where individuals can meet, interact, learn collaboratively and take collective decision". Hence, participatory processes are a means to enable and encourage social learning (MURO; JEFFREY, 2008), which is indispensable to SES transformation (MENZEL; BUCHECKER, 2013).

2.3 COMBINED ANALYTICAL FRAMEWORK FOR THIS STUDY

For the aim of this study and to answer the research questions, both frameworks outlined above were used in combination. The framework of Moore et al. (2014) was used to identify the current transformation status of SRL's dairy system and the elements needed to move the SES transformation process further forward to make it sustainable. This framework showed to be suitable to this case study since that "focuses on social-ecological transformations that are deliberate and actively navigated because of an understanding that the current ecological, social or economic conditions become untenable or undesirable" (MOORE et al. 2014, p. 3), which is the case of SRL. A group of researchers and extensionists from the Federal University of Santa Catarina (UFSC) and the Santa Catarina Agricultural Research and Rural Extension Company (Epagri) intentionally initiated a process of transformation using learning and participation processes as tools to deliberate the transformation process of the dairy system SRL, which was considered environmentally and economically unsustainable. Although Moore et al. (2014) refer to social learning as essential for transformation, their specification was not deemed detailed enough for this study. So, to allow for a more in-depth analysis, the framework of Moore et al. (2014) was combined with the triple-loop learning framework developed by Pahl-Wostl (2009) to identify in which level of learning SRL's dairy farmers already had achieved. Figure 2 shows the combination of approaches, in which it is possible to identify which type of learning level can be expected in each phase of the transformation. For example, in phase 'triggers or pre-transformation', single-loop learning is expected from people involved in the transformation process; while in phase 'preparing for change', single and double-loop learning can be expected, and so on.

Figure 2 - Methodological framework for the Analysis of the SES transformation of SRL's dairy system



Source: Authors' elaboration. Based on Moore et al. (2014) and Pahl-Wostl (2009).

3 METHODOLOGY

3.1 STUDY SITE

Santa Rosa de Lima is a small municipality located in Santa Catarina State in southern Brazil (see **Map 1**). The municipality is home to 2,065 people, whereof 75% live in rural areas. About 65% of the existing farms are engaged in dairy production (IBGE, 2010; 2006).

For this case study, it was selected 41 farmers. However this seems a small sample,that equals 35% of the municipality's dairy farmers, according to City hall records (oral communication, 2015). Our sample was composed by 21 farmers who already adopted MIG (MIG farmers), and 20 farmers who did not yet switch to MIG (non-MIG farmers), which are represented by the black and gray spots in **Map 1**, respectively. The type of system adopted by farmers was used as a criterion to sample, since we wanted to estimate the influence of system type on the performance of farmers. Participation of farmers was entirely voluntary and without any monetary compensation aimed at representing both, MIG and non-MIG, farmers equally in the sample, since we wanted a sample composed by 50% of each system type, which is very close to the participation of MIG and Non-MIG systems in the population of dairy farms of SRL (44.5% and 55.5%, respectively).

Map 1 - Location of Santa Rosa de Lima and farms sample

Note: Gray dots represent conventional farms and black dots represent MIG farms. Source: Brasileiro-Assing, 2018.

3.2 DATA COLLECTION

Interviews were conducted and recorded in SRL with the 41 selected dairy farmers during April and May of 2013. The questionnaire consisted of 176 questions regarding to family, activity and farm characteristics (Appendix A). Questionnaire was developed based on Meurer (2008), Schmitt Filho, Murphy and Farley (2010), Alvez (2012), Jeremias (2012), and Longo (2013).

From this initial sample, 35 farmers accepted to participate in an accounting project to evaluate financial and economic performance of the dairy farms. For that, accounting tables about production costs, income, investment and sales of dairy activity (Appendix B, C, D and E) were filled by farmers and collected monthly, during one year (August/2013-July/2014). During the project 3 farms withdrew, and during the data analysis 4 farms had to be excluded from the sample due to incomplete information, or because the income from the sale of animals was higher than the income from sale of milk (1 farmer). Therefore, our final sample size consisted of 27 farms, 15 using MIG and 12 using the conventional system. To calculate production costs, we used the absorption cost method, which includes variable and fixed costs. (see Appendix E for details). Profit was calculated subtracting the revenue from milk sale minus costs.

Secondary data was used to estimate the cost of MIG implementation. For that, we used the average of implementation costs calculated by Machado (2004), Dias (2014) and Moura et al. (2014), which resulted in 845,63 US$/hectare (see Appendix F for details).

3.3 DATA ANALYSIS

We applied the framework presented in Figure 2 to **analyze**: a) the current status of the SES transformation process of SRL's dairy system; and b) the level of learning that was achieved during each phase.

To analyze the differences between farm characteristics of the two groups (MIG and Non-MIG Farmers), we used t-test (T) for normally distributed data, and Mann–Whitney U test (U) for nonparametric data. These analyses were conducted using IBM Statistical Package for Social Sciences (SPSS) Version 23. We use significance (α) of 0.10, since these tests are influenced by the sample size.

To analyze the differences in the percentage of farmers using agrichemicals between MIG and non-MIG farms, which were binary variables, we used chi-square (x^2) for a two times two contingency table, with one margin fixed (number of MIG and Non-MIG farmers). For this test, we chose $\alpha = 0.05$, since this test is not influenced by a $n = 41$ (See Appendix C for details).

The assessment of learning effects was based on data obtained from the interviews in combination with author's observations obtained while conducting the interviews on the farms based on participant observation (cf. SPRADLEY, 1980). Therefore, reported learning effects were related to the different learning loops (cf. PAHL-WOSTL, 2009) and the different sub-processes in the transformation process (cf. MOORE et al., 2014).

4. RESULTS AND DISCUSSION

4.1 THE SES TRANSFORMATION PROCESS OF SRL'S DAIRY SYSTEM

4.1.1 Phase 1. Triggers or pre-transformation: concluded.

Moore et al. (2014) emphasize that the decline of ecosystem services can lead to a sudden reevaluation of management practices. The starting point of the transformation process of the dairy system in SRL, from conventional management to MIG, was triggered by the direct and indirect negative impacts of the management on farmers' economic performance and on the environment (SCHMITT FILHO; MURPHY; FARLEY, 2010), such as promotion of climate change due to soil organic matter loss, increased erosion and landslides, loss of soil biodiversity, and water and soil contamination (ZILBERMAN et al., 2011; BUSTAMANTE et al., 2012; SUTTIE; REYNOLDS; SABATELLO, 2005). These environmental disservices of the applied management practices (ZHANG et al., 2007), led to economic impairment, providing a strong incentive for change.

Initially, without an accounting record, farmers were unable to accurately state their economic losses or profits before MIG adoption. But when asked why they adopted the MIG system, 42% of them stated that they adopted MIG because of its promise of better economic results, and when asked if MIG allowed for the improvement of their quality of life, 100% of them agreed. Based on the accounting project (Table 2) it is possible to realize that, in average, non-MIG farmers are non-profitable. MIG farmers also stated a concern for environmental conditions as one reason to apply MIG, which was the second most mentioned reason. These initiated the transformation process, since the current SES conditions became undesirable. In this context, MIG was perceived as a more sustainable alternative to the conventional dairy system (ALVEZ et al., 2014), since single farmers in the region had already introduced MIG in the late 1990s with positive ecological and economical effects (SCHMITT FILHO; MURPHY; FARLEY, 2010). MIG allows to manage cattle, pasture and soil in such a way that animal forage, productivity, and stocking rates can be increased, increasing land efficiency (MACHADO, 2010; MURPHY, 2008; ALVEZ, 2012).

4.1.2 Phase 2. Preparing for change: partially concluded.

Sensemaking: This sub-process is characterized by the understanding of the current situation, by analyzing what elements of the SES make its current trajectory most problematic (MOORE et. al., 2014). The authors consider collective and individuals actors to prepare the system for change. In SRL's case, the Silvopastoril Systems and Ecologic Restoration Lab. (LASSre/UFSC)[1], from the Federal University of Santa Catarina (UFSC), was the actor that started this process (SCHRÖTER et al., 2015). Therefore, in SRL, the transformation was promoted and conducted by a small group, which engaged the local community in the transformation process. LASSre/UFSC and Epagri had already conducted many studies to better understand which factors made the conventional dairy system vulnerable and problematic (SCHMITT FILHO; MURPHY; FARLEY, 2010; ALVEZ; 2012; FARLEY et. al, 2012; SCHMITT FILHO et al., 2013). This included, the use of chemicals (which can be toxic to humans and livestock), low animal stocking rates (which imply a higher pressure for additional deforestation), overgrazing, and low pasture quality. These findings were shared with farmers, who accepted to be part of the pilot project for the MIG implementation. During 1999 to 2000, LASSre/UFSC and Epagri made one field day per month in the Santa Rosa de Lima, and during 2001 to 2003, they

1 - http://lass.paginas.ufsc.br/.

conducted two field days per month in the region. Through that, farmers understood and agreed that they were applying damaging techniques and consequently decided to apply more efficient land use and environmental-friendly alternatives, which shows achievements of single-loop learning in the SES transformation (PAHL-WOSTL, 2009).

Envisioning: This sub-process includes the analysis of the alternative practices from previous studies. This initial analysis were conducted by the proponents of dairy system in Santa Catarina (LASSre/UFSC) and then shared with farmers through field days and workshops. Research conducted on MIG adoption showed that its adoption provided greater pasture yields, allowed increased stocking rates, improving the density and quality of forage swards, reduces erosion, promoted nutrient cycling and decreased nutrient runoff into water bodies, thereby enhancing water quality (ALVEZ et al., 2014; DE RAMUS et al., 2003; ROTZ et al. 2009). MIG can also increase and positively influence biodiversity (MELADO, 2003) and promote greater storage of carbon in soils (TEAGUE et al., 2016; DE RAMUS et al., 2003). MIG relies on well-managed pastures and can potentially restore ecosystems services, and thus, enhance rural livelihoods (SCHMITT et al., 2013).

Besides the environmental advantages adopting MIG, the system also brings economic advantages. They include lower operating costs, reduction of labor requirements, decrease in animal health problems, lessening expenses attributed to crop production, resulting in higher net returns per cow or per unit of milk produced, lowering the risks related to relying on off-farm inputs (PARKER; MULLER; BUCKMASTER, 1992; HANSON et al., 2013; TAUER; MISHRA, 2006; GILLESPIE et al., 2009; WINSTEN et al., 2010). In this study, some of these advantages were confirmed. **Table 2** summarizes the differences between MIG and non-MIG farmers for several environmental variables (e.g. soil coverage, stocking rates, etc.).

Table 2 - General Management Intensive Grazing (MIG) and conventional system's economic, environmental and social performances and characteristics at Santa Rosa de Lima – SC, 2014

Variable	MIG		Non-MIG		p-value
	Mean or %	SD	Mean or %	SD	
Performance					
Farmers that have the pasture totally covered	81%	..	35%	..	0.003*
Stocking rate of pasture area (AU²/ha) for August/2013-July/2014	3.63	1.77	3.14	2.02	0.508
Presence of small animals in pasture has increase in the last 10 years	55%	..	35%	..	0.064*

Life quality has improved after MIG adoption	100%	..	..	..	..
Animal health has improved the last 10 years	95%	..	40%	..	<0.0001*
Workload has decreased the last 10 years	10%	..	50%	..	0.074*
Profit (US$/month/Hectare[1]) for August/2013-July/2014	29.25	57.55	-12.49	57.96	0.074*
Production Cost (US$/month/Liter) for August/2013-July/2014	0.47	0.22	0.65	0.22	0.037*
Demographic characteristics					
Number of young family members	1.00	0.89	0.55	0.75	0.09*
Number of adult family members	2.76	0.88	1.8	1.36	0.01*
Number of elderly family members	0.66	0.73	1.45	0.99	0.006*
Total of family members	4.42	0.98	3.80	1.44	0.11

Notes:
*denotes significance at $\alpha = 0.10$
.. denotes: not applicable
[1] That Includes the total area destinated for dairy activity (pasture and crop for silage production).
[2]AU denotes: animal unit, which corresponds to 450kg .

Source: Authors' elaboration.

Results show that MIG farmers performed better than non-MIG farmers on all variables, with statistically significant differences, except on 'stocking rate', for which the p-value was slightly greater than 0.5. Non-MIG farms reported greater bare soil ($p = 0.003$). Consequently, farmers had to produce more silage to meet animals' nutritional needs, which can increase overall costs and environmental impacts due to the production chain of those inputs. Most MIG and non-MIG farmers fed silage in the summer (60% and 88%, respectively), and 100% of them do it in the winter. Since forage growth is compromised by low temperatures during dry seasons and frosts in the wintertime, it can be expected that farmers would include silage as animal feed. In the summertime, forages have better biophysical conditions developing full growth potential thus, decreasing the need for silage because it can be stored for wintertime. As such, farmers are probably unnecessarily feeding animals with silage in the summer. On average, MIG farmers use 6.5 kg of silage per day while non-MIG farmers use 8.8 kg to feed each cow and heifer. So, non-MIG farmers need 36% more silage than their MIG counterparts, which in part is due to their degraded pastures originated from their poor grazing management. As presented in table 2, MIG farmers have enjoyed better pasture conditions than Non-MIG farmers.

The monthly profit per hectare for MIG farmers was positive, while Non-MIG farmers realized a negative profit with a statistically significant difference. These results surprised many Non-MIG farmers for two main reasons: a) most of them did not account or kept registries of their activities before the Accounting Project; b) they did not consider their labor as a cost of production.

The economic gains obtained from MIG farms alone would justify the adoption of the system. These economic gains could be even higher by further reducing costs of agrichemicals, which would provide additional environmental benefits through enhanced ecosystem services. However, MIG has not yet reached its full potential in SRL, as some of MIG farmers are still using agrichemicals, both on grass and on arable lands for silage production. Also, for this sub-process, single-loop learning can be observed through the incremental changes in the amount of established practices to improve the environmental performance of the system (PAHL-WOSTL, 2009).

Gathering momentum: This sub-process includes creating a network to build a shared identity for those desiring a transformation (MOORE et al., 2014). The built network was initiated as a pilot to experiment MIG on four farms, which became the point of origin for further upscaling processes in SRL (SCHMITT FILHO; MURPHY; FARLEY, 2010). One crucial pre-condition for upscaling is the ability to secure some funding and human resources. LASSre/UFSC, as the main initiator, was able to secure both, from several sources over time, e.g. Agricultural Science Center (CCA/UFSC), EPAGRI, SRL's City Hall, National Council for Scientific and Technological Development (CNPq), SEBRAE, Coordination for Qualification of Graduate Students (CAPES), Gund Institute for Ecological Economics from the University of Vermont (UVM), University of São Paulo (USP), and the CiVi.net project (funded through the European Union's 7th framework program). Over time, the majority of the team members were volunteers, undergraduate and graduate students from the agronomy program at UFSC (SCHRÖTER et al. 2015), local farmers, researchers from UFSC and later from the mentioned universities, and local technicians from EPAGRI. Additionally, a local actor, a community member, was included into the project to help to mobilize local community members.

4.1.3 Phase 3. Navigating the transition: in process.

Selecting: The selection of MIG, as the preferable and most promising alternative, was possible due to the clearly visible advantages of MIG in comparison to the conventional system, mentioned in the **envisioning** sub-process.

In the interviews, farmers adopting MIG stated six reasons for adopting the system: a) increase of land productivity (stated by 5% of farmers); b) received incentive from Epagri, UFSC or Dairy coop (stated by 9,5% of farmers); c) area optimization (stated by 9,5% of farmers); d) perceived good results in the neighboring farms already adopting MIG (stated by 20% of farmers); e) environmental improvements (stated by 28,5% of farmers); and f) expectations of profit increase (stated by 43% of farmers). Most of them adopted the system by recognizing its economic advantages. However, the improvement of environmental conditions, such as pasture resilience and animal health, was the second most important reason stated.

The improvement of the dairy system achieved by experimenting with MIG and the inclusion of ecological variables in the measure of performance give evidence of double-loop learning, which results in the revision of assumptions and a reflection of goals and problem framing (PAHL-WOSTL, 2009). The double loop-learning is assessed to be still in process in SRL, since MIG is not yet adopted by all/the majority of farmers. Besides, not all farmers stated environmental reasons for MIG adoption.

Learning: This sub-process implies evaluating the results of earlier pilot testing and developing a shared understanding or new forms of knowledge to help inform the selection process. This sub-process is crucial for social transformation, because, if this step is skipped, the understanding of the overall advantages (social, ecological and economic) of the new system can be too superficial not really implying a change in values and beliefs. In this case, the transformation process can still be abandoned by the limitations imposed by the vision of a single lens, for example, the economic lens.

In SRL, to push for a change in mindset, LASSre/UFSC, jointly with the City Hall and The Company of Agricultural Research and Rural Extension of Santa Catarina (EPAGRI), developed participatory processes. Meetings, workshops, group discussions and individual conversations were conducted. All MIG farmers recognized that these activities were important. However, in SRL, this learning sub-process still seems to be incomplete, since the activities to engage local farmers in environmental conservation were not enough to change their values beliefs in relation to nature yet. This is backed up by the fact that some MIG farmers are still using agrichemicals, such as fertilizers and herbicides. Surprisingly, the percent of MIG farmers using fertilizers and Herbicides was 76% and 48%, respectively, whichwas higher than non-MIG farmers at 48% and 20%, respectively. Statistical tests showed that the difference in fertilizer use was significant (see **Appendix E**). One possible reason to explain why MIG farmers kept using agrichemicals is the fact that in general, MIG farmers take pride on their dairy activities as perceived in the field work. Therefore, messy, overgrown weedy pastures 48% and 20%, respectively is something that is frowned upon their peer farmers and neighbors. In their view, a good farmer is the one who uses fertilizer, lime and keeps the pasture and cropland "clean", even if this implies using agrichemicals.

Although in the original concept of MIG the use of agrichemicals, such as fertilizer, are allowed (VOISIN, 1988), LASSre/UFSC and EPAGRI proposed MIG as an environmentally friendly alternative, relying upon livestock manure and nitrogen fixing legume forages. Nevertheless, some farmers adopted MIG without applying agrichemicals initially. Consequently, it was possible to establish the first organic dairy coop in Brazil, The *Geração* Dairy Coop in SRL, which was certified by ECOCERT in 2002[2]. However, the organic production lasted only three years, due to a high seasonal demand from the public school. As a result, the dairy coop decided to switch to producing conventional dairy products and the farmers who were producing organic quit and started producing conventional milk again.

2 - http://www.brazil.ecocert.com/.

Even farmers that took part in the participatory processes assisted by LASSre/UFSC and EPAGRI abandoned some of the ecological principles established when introducing MIG. This can be attributed to: 1) insufficient mobilization of the farmer communities; 2) misunderstanding of MIG as an agroecologically integrated activity by EPAGRI technicians; 3) agribusiness pressure on farmers and technical service providers to increase individual cow productivity at the expense of profitability and environmental health; 4) inadequate application of the tools to promote the participatory processes; or 5) lack of funds to keep participatory process of the outreach program. This could also be related to the prior emphasis on economic advantages of MIG by many farmers, as stated before.

Adoption: This sub-process refers to the widespread uptake and mainstreaming of the new system (MOORE et al., 2014). When the process of adoption is not assisted properly, it is possible that adopters change the initial proposal according to their prior interests, also supported by their lack of better knowledge. This seems to hold true for the case of SRL. LASSre/UFSC members did not visit and assist all the current MIG farmers in the adoption of the system, since they were only responsible for training the EPAGRI technicians to continue the work they started. Therefore, most of farmers are not adopting the system entirely as it was suggested by LASSre/UFSC and EPAGRI.

Currently, MIG is not yet adopted by all dairy farms in SRL and more than half (55%) of the dairy farms are still practicing the conventional system (SRL' city hall, 2015, personal communication). This can be explained by several obstacles as stated in the interviews. From the 20 non-MIG farmers interviewed in SRL, only five did not know about the system. After a brief explanation, it was asked to them if they believe that the system could bring environmental improvements and economic gains to their farm. All of them responded positively and gave reasons for not adopting the system. The three most mentioned reasons were related to: a) the investment cost to adopt the system (stated by 35% of the farmers); b) the labor required to set up and maintain the system afterwards (30%); and c) the physical indisposition of farmers with advanced age (30%). The other reasons cited were related to high slope of the terrain (20%), and the absence of knowledge on MIG adoption (10%). The reasons **b)** and **c)** can also be confirmed by the demographic data of the sample (see **Table 2**). In general, MIG farms have more family members working on the farm than non-MIG farms. By comparison, MIG farms have a higher labor input from young and adult family members, while non-MIG farms have more labor input from adult and elderly family members. Most differences found were statistically significant at p-value ≤ 0.10.

As mentioned before, 35% of the non-MIG farmers stated that one of the reasons not to adopt MIG lies in the fact that the adoption is too expensive, and they could not afford it (reason **a**). When asked about their interest in adopting the system in the future on the condition of receiving the necessary financial support, 70% of the non-MIG farmers stated that they were indeed very interested, 20% stated that they were not interested even if they had the necessary financial resources, and 10% remained undecided.

The transition from conventional to a MIG dairy system demands investments in fencing, to keep cattle rotating through daily paddocks and keeping them from entering into water bodies; water pipes, to install a watering system at the paddocks; and overseeding of winter forages (grasses and legumes).

The cost for implementing MIG averaged US$ 845.63/hectare. In SRL, the average area of pasture area per farm is 8.75 hectares. So, the costs in case of a transition from conventional to MIG would amount to an average initial investment of 7,399.26 US$ per farmer. In our sample, non-MIG farmers had a negative annual income of US$1,829.19 on average. Therefore, this kind of investment would constitute an extravaganza for any smallholder going through financial problems derived from conventional dairy systems.

4.1.4 Phase 4. Institutionalizing the new trajectory: in process to start.

Routinization: In this sub-process the newly formed knowledge on social-ecological feedbacks in the system become established and strengthened (MOORE et al., 2014). In the social system of the SES, this concerns to the standardization of the new MIG management practices that were adopted for the transformation of the system. For that, additional funding is crucial, especially for farmers who cannot cover the cost for MIG transition on their own, as mentioned before. Additionally, participatory processes and extension activities demand properly trained personnel. However, the programs and project grants fund only for a limited period of time and do not safeguard the continuous support that is needed to accomplish this phase. Against this backdrop, LASSre/UFSC, jointly with GUND/UVM and PROCAM/USP, have considered payments for ecosystem services (PES) as a viable alternative for funding to support continued implementation of MIG, and help to foster extension activities and participatory processes needed to ensure correct application of the system. MIG and non-MIG farmers were asked about their interest for taking part in the PES program and most of them (84% of MIG farmers and 63% of non-MIG farmers) reacted positively to the idea.

In the ecological system of the SES, this sub-process concerns to the stabilization of ecosystems to enhance the provision of ecosystem services and the preservation of the region's natural capital realized through the transformation process. As showed in **section 4.1.2 (see Table 2)**, farmers have very well perceived the environmental improvements for their dairy farms after the switching to MIG, which indicates a change of system towards a new trajectory more in support of sustainable development.

Strengthening cross-scale relationship: This sub-process involves scaling up the change, which often involves an adjustment of the original innovation to make it a good fit for the transfer regions. Here, in addition to the original MIG concept, LASSre/UFSC has integrated high-biodiversity silvopastoril systems (SPSnuclei) with applied nucleation (REIS; BECHARA; TRES, 2010), as well as living fences to their original idea (PITTON et al., 2014, SCHMITT FILHO et al., 2017). The system was designed through participatory research and aimed to: 1) enhancing animal wellbeing by providing shade for the animals with native trees; 2) improving livelihood through the produce of non-timber forest products in the nuclei; and 3) restore the highly *anthropized* rural landscape of the Atlantic Forest Biome. The SPSnuclei is in testing phase on six farms (SCHMITT FILHO et al., 2017).

Stabilization: For this sub-process, a change in the underlying norms and values (triple-loop learning) is expected. Even if the transformation process has reached some degree of stabilization, this sub-process cannot be seen as final, since there can be resistance over time, when unintended negative consequences occur (MOORE at. al, 2014). Currently, the SES transformation of SRL's dairy system has neither achieved stability, nor a triple-loop learning. For that, the agents interested in this transformation first need to realize a more sustainable trajectory and resist attempts to revert from the current trajectory of transformation (MOORE et al., 2014). The continued use of agrichemicals by MIG farmers is one indication that such resistance still prevails in the system that might compromise a successful completion of the desired transformation process.

5. CONCLUSION

Regarding the transformation, based on the results presented in the previous sections, it seems clear that a process of SES transformation is currently taking place for the dairy system in SRL. In summary: a) farmers have partially recognized that the conventional dairy system has become intolerable due to the associated environmental disservices that challenge the continued functioning of the SES; b) MIG has emerged as a new and more sustainable system which can replace the conventional one; c) social networks have been developed among farmers, researchers (LASSre/UFSC, GUND/UVM, PROCAM/USP), and government agencies (Epagri), which push the transformation process forward to change from the conventional system to MIG; d) attempts to build a common knowledge base to the benefit of all involved actors within the network has been successful; and e) efforts to replicate and upscale MIG within the region has been taken place, and currently already 44.5% of SRL's famers have adopted the new dairy system.

About the learning processes, since it is very complex to measure the level of learning, results are less clear. But based on the fact that MIG farmers have already realized incremented improvements in the establishment of MIG routines, it is possible to state that MIG farmers have already accomplished at least the single-loop learning. They also seem to have started to make progress in regards to the double-loop learning, since they have been reflecting on their actions and underlying value and belief systems with the result that a considerable number of farmers has already switched to MIG reducing environmental damage to their region. Nevertheless, MIG farmers did not seem to have a complete change in value and beliefs. This is evidenced by the fact that the economic benefits from the system are still the main reason for its adoption, and that farmers are still willing to use agrichemicals. This evidences that environmental responsibility is not yet embodied into farmers' values and beliefs. There is still a need to keep up the effort to start the process of learning. A new paradigm needs to be established and for that, continuous attempts of participatory processes are recommended. It is also important to mention that the process of change of values happens gradually and slowly, and that it is naïve to assume that beliefs and values that were built during centuries can be changed in just a few decades.

Altogether, the SES transformation of SRL's dairy system seems to be in the middle of the process, where more must be achieved to complete the transformation of the system. As our analysis was primarily based on observed farmers' behaviour and their perception as captured in the interviews, for further research, it would be interesting to include the perceptions of other actors involved in this process. This includes researchers, undergraduate and graduate students, government agencies personnel, consumers, processors, distributors, wholesalers, retailers, etc.

Additionally, considering that some of the non-MIG farmers simply did not adopt the new system because they do not have the necessary financial capital for that, the introduction of a PES seems very promising in order to leverage additional funds to support farmers currently not able to cover the required upfront investments on their own, to adopt the system. Since MIG creates several ecosystem services (e.g. soil conservation, carbon storage, biodiversity protection, etc.), valued by different groups, it seems doable to raise enough willingness to pay funds for such services among them. Also, a first condition for the success of the PES was indicated already by farmers' willingness to act as ecosystem service providers for the PES.

So a PES scheme would be a very promising option to explore in the future, to provide more financial capital needed to sustain the transition process, and the participatory processes needed to foster favourable conditions for social learning, for rising environmental awareness, and consequently collective action. This could result in a paradigm shift towards implementing more environmentally friendly and sustainable farming in SRL.

As a final note, the framework built for the analysis in SRL, seems also suitable for the analysis of transformation processes and learning effects in other contexts and in other regions.

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Andréa Castelo Branco Brasileiro-Assing -
✉ andreacastelobranco@gmail.com
ORCID: https://orcid.org/0000-0001-5536-3149

Claudia Sattler
✉ csattler@zalf.de
ORCID: https://orcid.org/0000-0002-5588-5075

Barbara Schröter
✉ Barbara.Schroeter@zalf.de
ORCID: https://orcid.org/0000-0001-8066-8446

Juan P. Alvez
✉ jalvez@uvm.edu
ORCID: https://orcid.org/0000-0002-9661-6525

Paulo Antônio de Almeida Sinisgalli
✉ psinisgalli@usp.br
ORCID: https://orcid.org/0000-0001-7822-3499

Abdon Schmitt Filho
✉ abdonfilho@hotmail.com
ORCID: https://orcid.org/0000-0002-3553-7727

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Transformação Social-ecológica e aprendizagem: o caso do sistema de produção de leite de Santa Rosa de Lima, Brasil

Andréa Castelo Branco Brasileiro-Assing
Claudia Sattler
Barbara Schröter
Juan P. Alvez
Paulo Antônio de Almeida Sinisgalli
Abdon Schmitt Filho

São Paulo. Vol. 24, 2021

Artigo Original

Resumo: O manejo convencional de pastagem tem levado produtores do Sul do Brasil às crises financeiras e ambientais. Neste contexto, o sistema de Manejo de Pastagem Intensivo (MPI) surge como uma alternativa ao convencional. Este estudo analisa o processo de transformação do sistema social-ecológica de produção de leite, do manejo convencional para MPI, do município de Santa Rosa de Lima. Para esta análise, foram combinadas duas diferentes abordagens: a abordagem do processo de transformação de sistemas social-ecológicos e aprendizagem de triple-loop. As análises se basearam em análises estatísticas de entrevistas a produtores de leite. Os resultados mostram que o sistema de produção de leite em Santa Rosa de Lima está no meio do processo de transformação. Nesta fase, produtores têm já alcançado aprendizagem de single e, parcialmente, double-loop. Entre os elementos necessários para continuar com sucesso o processo de transformação, aprendizagem social e capital financeiro apresentam-se como indispensável. Para isto, sugere-se pagamento por serviços ecossistêmicos.

***Palavras-chave*:** Sistema social-ecológico; sistema de produção de leite familiar; aprendizagem de triple-loop; capital social.

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SciELO

Transformación socioecológica y aprendizaje: el caso del sistema de la producción lechera en Santa Rosa de Lima, Brasil

Andréa Castelo Branco Brasileiro-Assing
Claudia Sattler
Barbara Schröter
Juan P. Alvez
Paulo Antônio de Almeida Sinisgalli
Abdon Schmitt Filho

São Paulo. Vol. 24, 2021
Artículo original

Resumen: El manejo convencional de los pastos ha llevado a los productores del sur de Brasil a crisis financieras y ambientales. En este contexto, el sistema de Manejo Intensivo de Pastoreo (MIP) aparece como una alternativa al manejo convencional. Este estudio analiza el pro ceso de transformación del sistema social-ecológico de producción de leche, del manejo convencional para MPI, del municipio de Santa Rosa de Lima. Para eso, se combinaron dos enfoques diferentes: el proceso de transformación del sistema social-ecológico y el aprendizaje de triple-loop. Los análisis se basaron en análisis estadísticos de entrevistas con productores de leche. Los resultados muestran que el sistema de producción de leche en Santa Rosa de Lima está en medio del proceso de transformación. En esta fase, los productores han alcanzado el aprendizaje de single y, en parte, double-loop. Entre los elementos necesarios para continuar con éxito el proceso de transformación, el aprendizaje social y el capital financiero se presentan como indispensables Para eso, sugerimos adoptar un sistema de pagos por servicios ecosistémicos.

Palabras-clave: Sistema social-ecológico; sistema de producción de leche familiar; aprendizaje de triple-loop; capital social.

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