A participatory modeling experience with young farmers: assessing the sustainability of family farming in Brazil

Modelagem participativa com jovens agricultores: avaliando a sustentabilidade da agricultura familiar no Brasil

Modelado participativo con agricultores juveniles: evaluación de la sostenibilidad de la agricultura familiar en Brasil

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Abstract
In Santa Rosa de Lima - SC - Brazil, a small municipality in South Region mainly covered by Atlantic Rain Forest, there is an effort to promote agroecology as socio-ecological improvement for family farmers. Part of this effort was conducted with young farmers in a debate about their land-use practices and the consequences of diversifying their activities. This study describes the process of a participatory modeling approach carried out in a workshop with young farmers to co-design conceptual models for land use practices. As results, a system dynamics model was built to represent their reality. The results of the workshop were embedded in a model to simulate a typical local property and provide insights into the consequences of diversifying their agricultural production by using the agroecological practices. Finally, the work presents the designed model and the first outcomes of scenario simulation, discussing the use of system thinking approaches in participatory modeling.
Keywords: Agroforestry systems; Socio-ecological modeling; Vensim; Scenario building; System practice; System dynamics.

Resumo
Em Santa Rosa de Lima - SC - Brasil, pequeno município da Região Sul coberto principalmente pela Mata Atlântica, há um esforço para promover a agroecologia como melhoria socioecológica para os agricultores familiares. Parte desse esforço foi realizado com jovens agricultores em um debate sobre suas práticas de uso da terra e as consequências da diversificação de suas atividades. Este estudo descreve o processo de uma abordagem de modelagem participativa realizada em uma oficina com jovens agricultores para o codesenvolvimento de modelos conceituais para práticas de uso da terra. Como resultados, um modelo de dinâmica de sistema foi construído para representar sua realidade. Os resultados da oficina foram incorporados em um modelo para simular uma propriedade local típica e fornecer insights sobre as consequências da diversificação de sua produção agrícola utilizando as práticas agroecológicas. Por fim, o trabalho apresenta o modelo desenvolvido e os primeiros resultados da simulação de cenários, discutindo o uso de abordagens da teoria do pensamento do sistêmico na modelagem participativa.

Palavras-chave: Sistemas agroflorestais; Modelagem socioecológica; Vensim; Construção de cenário; Prática de sistemas; Dinâmica de sistemas.

Resumen
En Santa Rosa de Lima - SC - Brasil, un pequeño municipio de la Región Sur cubierto principalmente por la Selva Atlántica, se realiza un esfuerzo para promover la agroecología como mejora socioecológica para los agricultores familiares. Parte de este esfuerzo se llevó a cabo con los jóvenes agricultores en un debate sobre sus prácticas de uso de la tierra y las consecuencias de diversificar susactividades. Este estudio describe el proceso de un enfoque de modelado participativo llevado a cabo en un taller con jóvenes agricultores para co-diseñar modelos conceptuales para las prácticas de uso de la tierra. Como resultados, se creó un modelo de dinámica del sistema para representar su realidad. Los resultados del taller se integraron en un modelo para simular una propiedad local típica y proporcionar información sobre las consecuencias de diversificar su producción agrícola mediante el uso de las prácticas agroecológicas. Por último, el trabajo presenta el modelo diseñado y los primeros resultados de la simulación de escenarios, discutiendo el uso de enfoques de pensamiento del sistema en el modelado participativo.
Palabras clave: Sistemas agroforestales; Modelado socioecológico; Vensim; Construcción de escenarios; Práctica de los sistemas; Dinámica de los sistemas.

1. Introduction

The critical challenge of increasing or at least maintaining the rate of production and simultaneously restoring the ecosystem services, which is indispensable for human well-being and even for the continuity of agricultural practices, is gaining a foothold in the international committees of policymakers (Grau et al., 2008; FAO, 2014). The agricultural sector is recognized as the main responsible for changes in biodiversity throughout history, accounting for 70% of the loss of projected terrestrial biodiversity (SCBD, 2014). This alarming scenario, on the one hand, demands new and urgent innovative methods for food production (Scherr & Mcneely, 2008), which requires behavioral efforts inconsistent with current trends of land degradation and the decrease of ecosystem services (MEA, 2005). On the other hand, optimists see opportunities for new markets targeting "eco-friendly" consumers and new ways to assess the funds allocated to suppress the demand for socio-environmental projects seeking eco-efficiency (Reith & Guidry, 2003). In any case, something intermediate can be achieved by continually redesigning models focused on local realities that gradually increase in scale, enabling changes in collective focus to alternative forms of supply chains and food consumption (Goodman, 2004).

Brazil faces the same dilemma and the trade-offs involving increasing food production and avoiding biodiversity loss is under central discussion at national policy debates (Martinelli & Filoso, 2009). Recently, the Forest Act - also known as Forest Code (BRASIL, 2012) - responsible to rules the land-use, especially setting preservation areas, has been reviewed. The further decisions might have a significative influence in farming activities dynamics (generally), and to family farmers (specifically).

Perhaps some topics are still under discussion, the new format of the Act has permitted “biodiversity-friendly” agricultural practices - at family farmers properties - in areas previously restricted for preservation reasons. The actual context is dividing opinions. By one side, preservationists consider the new Act overly permissive. Oppositely, ruralists argue that because of the country's proportion and the importance of agricultural products as the primary commodity, the new Act might be more permissive regarding agricultural land-uses. The new scenario, although criticized as a step back in forest conservation (Sparoveck et al., 2012) brought advantages to family farmers and allowed them to seek for alternative agrarian practices following the new Act.

Decades before the revision of the Brazilian Forest Act scientists and practitioners engaged on methods to restore degraded ecosystems in the way of balancing economic feasibility and increase on biodiversity and ecosystem services. That is the case of the Atlantic Forest Restoration Pact (Rodrigues, 2009), which aims to increase remnant Atlantic Forest from 17% of land cover today to 30% by 2050 and generate jobs opportunities by stimulating compliance with FC 2012 through incentives for landowners (Calmon et al., 2011).

Another initiative dedicated to face this challenge has been developed by a team of scientists at UFSC's Silvopastoral Systems Lab - LASS and extension agents of EPAGRI to help smallholders to improve farmer livelihoods. The work aims to help family farmers to comply with the National Forestry Code and the Atlantic Forest Law while restoring critical ecosystem services. The group is continuously codesigning, implementing and evaluating high biodiversity silvipastoril and agroforestry systems (HBSAS). During this process, the group brought up some questions such as: How the implementation of HBSAS is affecting the dynamics of ecosystem services? Who are the potential beneficiaries of the ecosystem services provided? Which policies could support HBSAS implementation and increase farmer incomes by restoring the Atlantic Forest and the services it generates in compliance with the new forest code?

Independent of the method recurred to help to answer these complex questions, it is becoming at utmost importance that cases where local farmers are the protagonists - most affected by the final results, also having the last word about the project implementation - their engagement becomes crucial to the achievements of these goals (Allen & Kilvington, 1999; Irvin & Stansbury, 2004; Oteros-Rozas et al., 2015). Though there are a diversity of possible methods to this end, this work concentrates on the modeling techniques, derived from the system thinking theory (Checkland, 1999), generally assumed here as Participatory Modeling (PM), and the implications to involve young farmers into the model conceptualization stage.

PM is defined by Voinov et al. (2018, p. 2) as "a purposeful learning process for action that engages the implicit and explicit knowledge of stakeholders to create formalized and shared representations of reality." It is considered an "umbrella" concept, subject to criticism regarding its practice, implications and even the idea of participation itself (Jordan et al., 2018). Voinov & Bousquet (2008) say it has recently become a "must" to involve stakeholders in modeling processes that focus on public policies. Although they argue PM not necessarily secure the acceptance or the efficiency of the policies and decisions assisted through this process, it appears to be helpful in collaborative learning processes.

Voinov et al. (2016) reassured the importance of stakeholders' participation in the whole modeling process and reinforced that even after many attempts there is no single way of doing PM, as the approaches may vary depending on the circumstances. They reinforced the necessity of increasing participation in the whole process of modeling, heightening the sense of ownership of the participants, or how to better communicate the results of the model in a consistent and natural language for the participants with the most different backgrounds and education levels.

We based our framework in Rosalind Armson (2011, p 163) idea of co-designed diagramming, which states:

> "…deeper engagement comes from drawing diagrams together as a joint enterprise. Diagramming in groups is challenging. It quickly reveals the diversity of perspectives so that they can be discussed, widening the perspective of each diagrammer. Once the tensions of surfacing different perspectives resolve, diagrammers can then incorporate a wider range of knowledge and understanding, producing a richer diagram and expanding everyone's mental models of the situation".

According to this logic, instead of applying methods to test hypotheses, the work describes the decisions made by the workshop facilitators to co-design a model with young farmers to represent their reality as a socio-ecological system. Then, it presents the results of the workshop and discusses the methods applied.

Among the portfolio of methods to involve stakeholders in a participatory modeling process (Voinov, 2018), a conventional approach to engaging them at any phase of the process is by facilitating workshops. As Vennix et al. (1990) explain, the process of a workshop can lead to a significant advance in knowledge elicitation and model development. We recurred to workshop facilitation but decided first to give the participants a task to create their Conceptual Model (CM) and use it in the stage of modeling designing. By inverting this order, we expected to increase their creative capacity; consequently, the emergence of new insights, while avoiding the biases of facilitators imposing a dominant perspective. Besides that, exploring first the young perspectives of the context before involving their parents into the process would also avoid the bias of family hierarchy dominance.

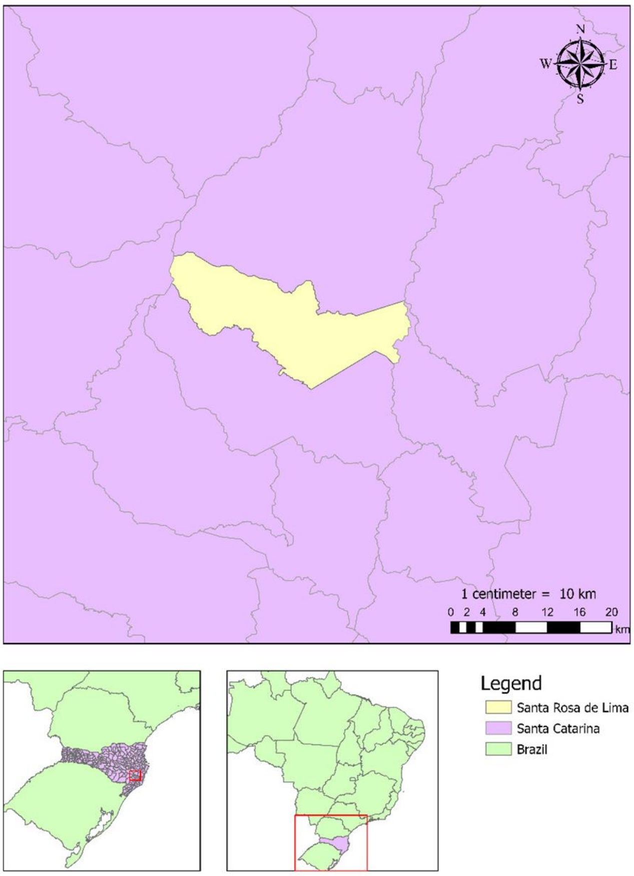
This work is a contribution to the systems thinking movement and is based on the learning cycle idea (Checkland, 1999) when the practical experience enriches the ideas, which subsequently inform the practice, engendering a continuous interactive cycle. Accordingly, the work has the objectives of 1. describe the method choice and its application; 2. present the conceptual models designed during the workshop; 3. describe how the CM was used to generate a stock and flux model; 4. show a baseline model simulation representing some participants concerns.

2. Methodology

2.1 Study area

The study area is the municipality of Santa Rosa de Lima (SRL), SC, Brazil (Figure 1). The city has 20,300 ha, with a population of 2,065 inhabitants (IBGE, 2010), located at southeastern of Santa Catarina's State. It is characterized by rugged terrain, with an average altitude of 240 meters above sea level. The predominant vegetation is a dense Atlantic rainforest, with some transitions to a mixed rainforest, with various and distinct microclimates (Vandresen, 2005).

Figure 1. Location of Santa Rosa de Lima. The colors indicate as follow: Green (Brazil); Purple (State of Santa Catarina); Yellow (Santa Rosa de Lima).



Source: Developed by the authors using ArcGIS 9.1

The most significant economic sectors of Santa Rosa de Lima are farming (32%), services (30%) and industry (5%).

The agricultural activities include the cultivation of vegetables and tobacco, and livestock farming, including dairy and beef cattle (IBGE, 2013). The city is considered "the agroecology capital" of Santa Catarina State, particularly by organic dairy production.

The case study was conducted by quantitative and qualitative methods (Pereira et al., 2018). Qualitative, by recording the workshop, interpreting, and discussing participants perspectives of the process. Quantitative, by selecting the most relevant terms according with their rate of appearance in the Causal Looping Diagrams (CLDs), as well as the data input into the system dynamic model to have a numerical representation of the young farmers reality and run simulations.

2.2 Workshop description

The methodology of the PM process was based in the theoretical construct of system thinking (Senge, 1990; Checkland, 1999; Jackson, 2003) and the work of Vennix (1990) to guide the overall workshop design and conduction. The idea of producing diagrams was grounded in Morecroft (1982), when incorporating the systemic view to help participants to identify the key sectors of the system and how they interact. Also, the works of Laniak et al. (2013); Voinov & Bousquet (2010); and Voinov & Gaddis (2008) to direct the pathways of Integrated Environment Modelling process, bringing examples of interactions between practitioners and stakeholders.

Following the premise that participatory modeling is the best way to construct a model relevant to both the local stakeholders and scientific communities (Jakeman et al., 2006), the model design was based in conceptual models developed by young local farmers who are gradually assuming the management of their relatives' farms. The reason to select them first was the assumption that if the workshops were conducted in the presence of their older relatives or other stakeholders, would increase the chances of young participation be less expressive, once they could feel embarrassed to take the floor. By hearing young people's voices before involving adults, we intend to adopt the behavioral lenses (Hämäläinen, 2015) and avoid possible overinfluence of parental hierarchy, where the adult´s voices dominate and pre-frame the inquiry.

We started with the subgroup of stakeholders which usually have less voice in the process of planning, to gradually insert the subgroups more likely to have a different level of influence in the context of the workshop. By reducing parental dominance, we expected to incentivize the creative capacity of the young farmers and to increase their interest with the modeling task. We also refused to use a different design method to deal with young farmers, believing they might be capable of understanding and actively participate if we used the same method thought for the adults. This decision encompasses the possibility of comparing the conceptual models created by young adults with those crafted together with their parents or other subgroups of stakeholders.

The workshop had six main purposes; 1. bring community closer to the modelers and increase they trustworthiness about the modeling process and results; 2. mapping out the diversity of points-of-view regarding their daily routine and how it is linked with different aspects of their community dynamics; 3. promote knowledge exchange between participants to identify common perspectives and accommodate differences; 4. identify elements to contribute to the process of model codesign to represent their context as a socio-ecological system; 5. investigate how they relate those elements with agroforestry systems; 6. Increase their familiarity with the system thinking language by "translating and reflecting back the stories that are important to the community using the visual language of system dynamics" (Hovmand, 2014, p. 33).

The workshop was held in seven hours, from 9:00 am to 4:00 pm, with one-hour lunchbreak. The program began with a small presentation about the intentions of the project "Analyzing ecosystem services from agroecology in the Atlantic Forest: a participatory modeling approach", and an explanation of the technique associated to system dynamics modeling (especially the construction of CMs). Then three questions were presented to guide the brainstorm and the CM production.

This activity took about 1,5 hours, and participants were divided into groups of four people. Three groups composed of young local farmers, one group of graduation students that conduct research in the area, and one group of the professors responsible for the study and a member of an extension institute that assisted the workshop organization. The last group had a task to try to delineate how the government actions are inserted in the socioecological dynamic of the region.

The participants had 4,5 hours (including the lunchbreak) to do a brainstorm and create a CM representing socioecological elements of their region, as well as reflecting on how the elements are interconnected. At the end of this activity, each group created a CM representing the system. The following activity was a presentation and an opened discussion of each CM to demonstrate how the groups accommodate their different points of view, also to align the thoughts of all participants. In the end, participants evaluated the workshop, and the facilitators explained the next steps of the modeling co-development. During this activity, each member pointed out the strengths and weaknesses of the workshop and suggested future improvements.

2.3 Model development based on the workshop results.

Using the workshop results, we designed a CLD incorporating the variables and relations produced, mainly focusing on the groups of young farmers. Through bibliographic review we incorporated variables that represented the reality of a local farm, such as the price of some commercialized products and the number of cattle per hectare, resulting in a stock and flux model. These parameters were collected from SEBRAE (2010), Instituto CEPA (2017), along with the interviews conducted by the research team of LASS/UFSC, which have been working with the local farmers since 1998. The agritourism parameters were based on Boeira (2008).

We ran the model's draft, using the variables to simulate how its dynamic would respond in a scenario of high biodiversity silvipastoril and agroforestry systems implemented. Also, simulated how some features of local aspects represented by young farmers (e.g., rural tourism and family succession) influences the dynamics of the system modeled. At this stage, it was possible to produce a reference model (Randers, 1980), which is useful to show the participants some features and utility of the model.

The modeling technique applied was the System Dynamics, first described by Jay Forrester (1968), frequently used to provide insights to policymakers and stakeholders about systemic results of changes in parts of complex systems. This method was used in many other cases described in Andersen & Richardson (1997), Voinov & Gaddis (2008), and Ford & Hegerty (2017), likewise more recent ones, such as Sanò et al. (2014) and Walters et al. (2016). These works involved some degree of participatory modeling and interactions with stakeholders to construct models, but they are mostly focused on general stakeholders' inclusion resorting to structured methods, such as causal matrix (Sanò et al., 2014). The difference in our approach is that we are beginning with a subgroup of stakeholders (young farmers) and we will gradually incorporate other subgroups in the next stages of the project.

3. Results and Discussion

The workshop resulted in five CMs (Figure 2) created by the participants. From these CMs, we divided the variables in seven subcategories (Table 1) to merge the CMs into a unique CM.

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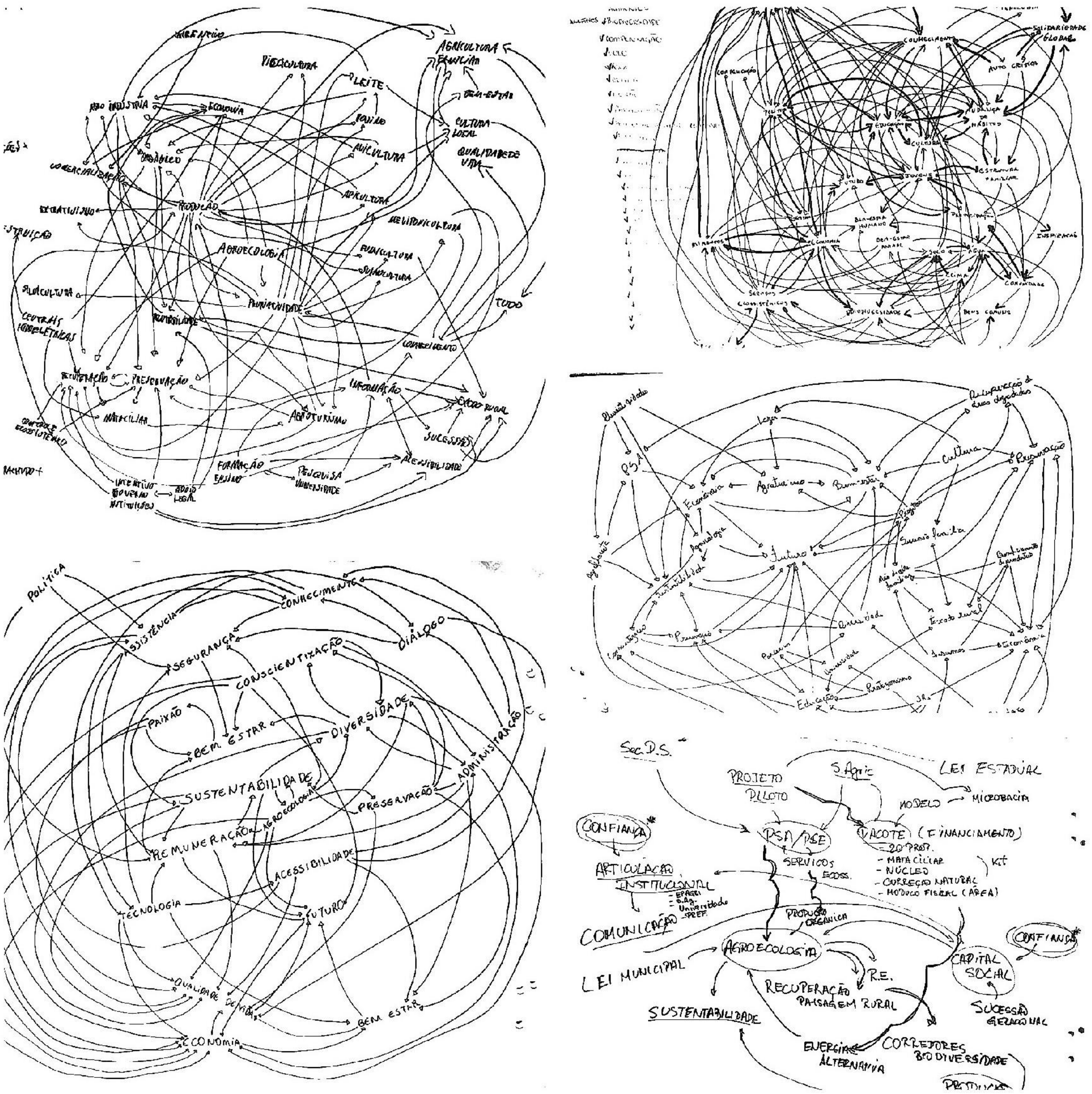
Figure 2. Causal Looping Diagrams developed by the workshop's participants after a brainstorm where participants were asked to mention terms that would represent their reality and represent how they are connected by influencing each other.



Source: Developed by the authors

Table 1. Elements identified on workshop diagrams according with their rate of appearance to be inserted in a system dynamic model that would represent the context of the study area according with the collective perspective of the participants.

Multi-activities	Rural Tourism Agroforest Tobacco Pigs Cows (Milk and beef) Chickens Honey (Native bees and Apis) Agriculture (Kibble, fruits, corn, sugar cane, and others) Fish Eucalyptus and Pine Sheep
Production	Organics Conventional
Government incentives	Direct incentive ($$) Payment for Ecosystem Services - PES Capacitation
Sustainability	Preservation x Conservation Economical use x Conservation
Economic aspects	Income
Indirect Benefits	Well-being Life quality Ecosystem Services
Social Aspects	Family succession Rural Exodus Tradition and cultural heritage preservation Small Farms

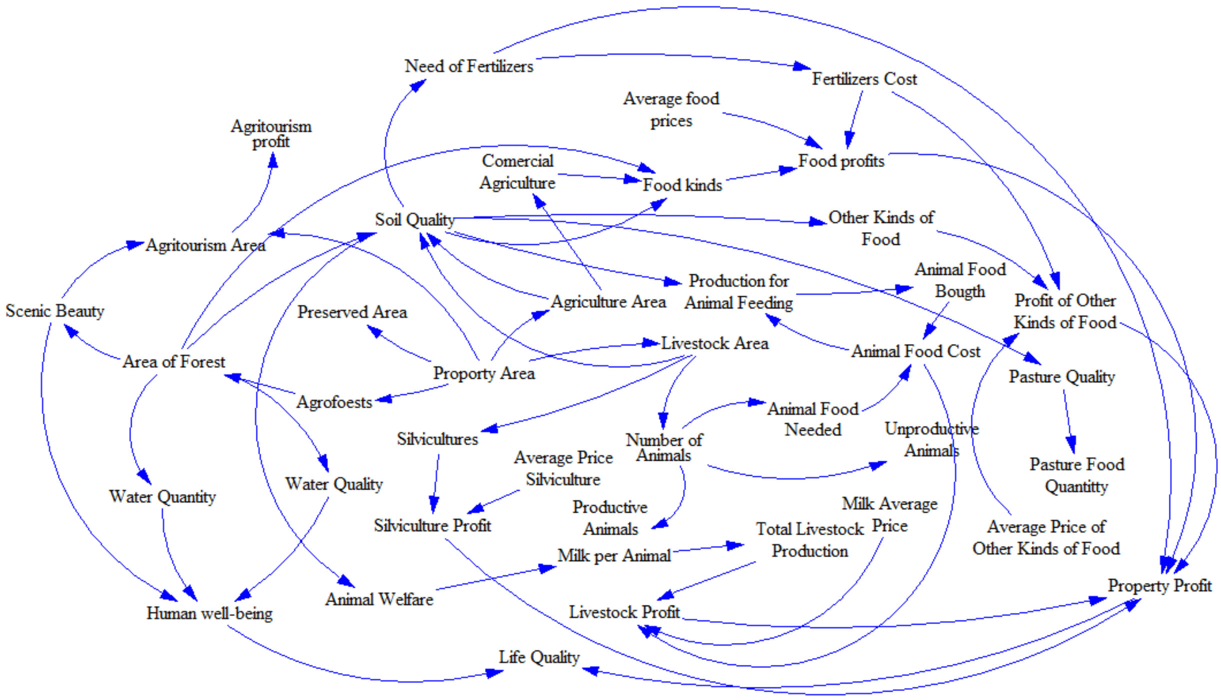
Source: Authors.

The variables and relations identified by the farmers were used to design a CLD to serve as a base to the stock and flux model (Figure 3). Although we present the whole CM in figure 3, the model does not encompass all the elements. The model was constructed over the core of the diagrams designed by the young farmers to maximize its acceptance in the community and facilitate the communication of the results in a next stage. This choice of modeling path leads to a reasonable economical model, which represents what appears to be the most significant question for the young farmers: is the farm economically sustainable to live from, or would be necessary to find a job in the city? This question is evident when three diagrams represented "Rural Exodus" (Exodo Rural, in Portuguese), mostly connected with an economic variable, reinforced during participants presentation of their CM, also when they expressed their impressions about the workshop activities. In a broader context, the young farmers seem to be afraid of their life on the farm and their long-term goals. This result was helpful to indicate their concerns about the situation under discussion. Even with our intention to include the agroforest systems (which was voluntarily represented at some point), our choice to start the process given them the freedom to represent their reality with their own words have uncovered some characteristics of the system that could be left behind if we had introduced them a pre-conceived model before the exercise. We follow the logic of Hovmand (2014, p. 33) when describing the community-based system dynamics notes:

> "…the model does not begin with the scientist's or policy maker's preconception of what the problem is, but with the issues that the community identifies and in their language. One starts with where the community is at and has to trust that the "right" model will emerge through a process of participatory modeling."

For the next stages, the workshop must be improved to participants generate a CLD and incorporate the use of system dynamics language. The time length to introduce the idea of conceptual mapping was enough, but the way we explained the CM was the trigger point to the diagrams that we received. Based on participants' feedback, we understood some deficiencies when explaining the process of designing CMs, which might be useful for future workshops. It was necessary to avoid some vague components (e.g., Future), what seems to be resulted by deficient conceptual model explanation.

Figure 3. CLD used to base model development after inserting the elements identified by participants. The CLD represents the dynamic of the elements in terms of how they influence each other as a first step before including numerical data in the model.

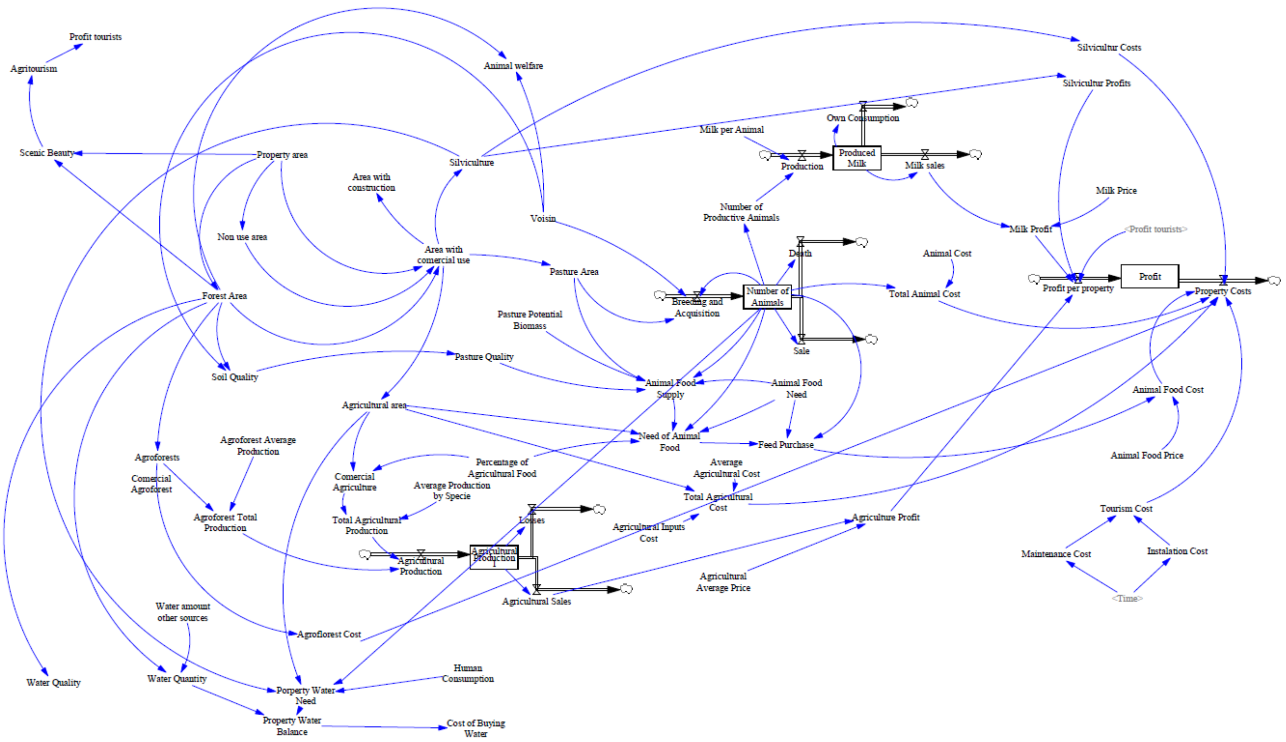


Source: Developed by the authors using the software Vensim 2.0.

We used the CM to develop a stock and flux model (Figure 4) and to simulate the reality of the family farmers. The development started with the farms size and the propriety areas distribution in its multiple uses, such as housing, pasture, agriculture, forest, and non-use areas. From this point, the model explores the economic activities of the land to generate the products that would be commercialized by the farmers, looking to the number of animals and milk production, agroforestry products and agriculture products. On the one hand, the farm income is the primary variable evaluated, based on these regular activities. On the other hand, the application of the Voisin, the agroforestry practices, and the scenic beauty from the preserved forest generate a tourism demand that they considered to have recently increased in the region, being considered as a secondary economic option.

Through the model constructed, we ran simulations using local data for each of the variables to evaluate the model structure and the consistency of the equations. The test resulted as expected once the milk, agroforest, agriculture production, and the tourism had a positive balance, and the profit stock showed a linear growth in the accumulated profit over the months (Figure 5)

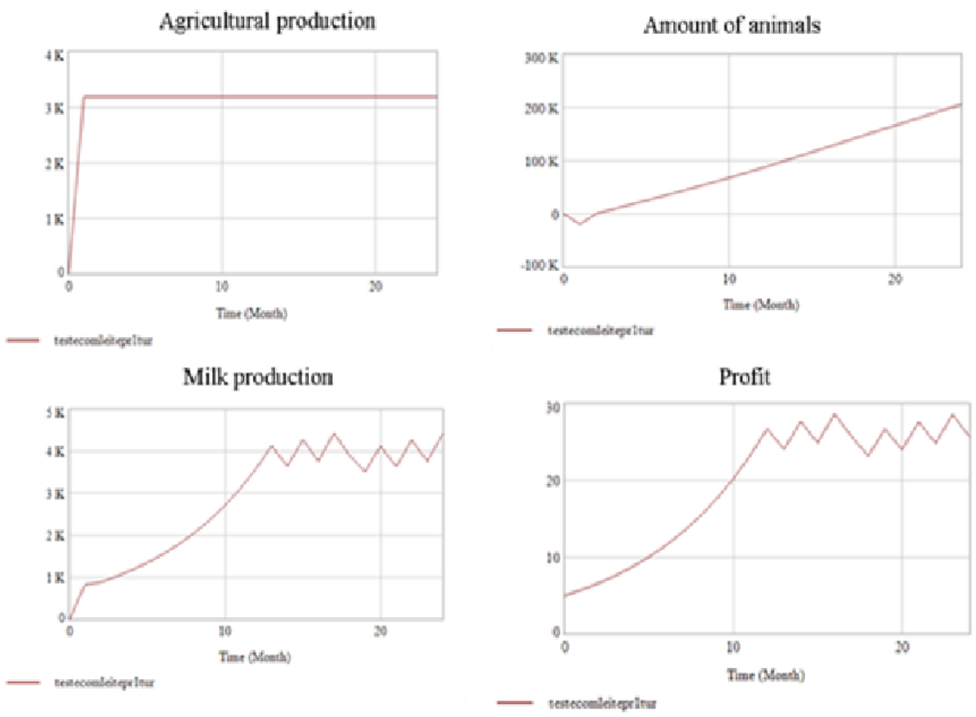
Figure 4. Stock and flux model representing a farm with the characteristics described by participants. The stocks are Produced milk, Profit, Number of Animals, and Agricultural Production. The other elements are variables that influences the model dynamics.



Source: Developed by the authors using the software Vensim 2.0.

We simulated a farm adopting the Voisin pasture method, which allows the density of 1,5 animals/hectare and the milk production of 11 liters/day/animal. Also, the agroforest area producing 650 kg/hectare/month. We considered the average price of R$1,30 for the agroforest products and R$0,75 for the milk. Also, the tourism demand of 220 tourists per month, with the accommodation cost around R$100/tourist/night. The property is deemed to have 35 ha, which is the average size of a property in the region. The land-use was considered as 5% of non-used areas, 20% of forestry (including protected land and agroforests), and 75% of commercial use (including constructions, pastures, and plantations). The baseline scenario (Fig. 4) is the reference for the next stages of the PM process when different scenarios will be simulated by changing the values of some variables.

Figure 5. Results from the model simulation representing a baseline scenario using a 20-month timescale to demonstrate the variation of the amount of agricultural production, milk production, animals, and the profit.



Source: Developed by the authors using the software Vensim 2.0.

At this stage, when stakeholders have to "play" with the model, we expect to deepen their understanding of how changes in some parameters would lead to changes in the dynamics of the socio-ecological system being modeled. For example, they can simulate the milk price dropping 10% and the touristic occupation rate increasing 25%, to have a better idea of how the net income would be affected.

4. Conclusion

The process of creating a meaningful model to represent the options and the context of a community starts with the involvement of its members in as many steps as possible during model development (Hare et al., 2003). During the modeling process, the stakeholder's participation usually reveals some insights about the context and the elements of the system modeled. Accordingly, we considered the workshop as a useful stage to expand the understanding of facilitators and participants of the challenges of being a young farmer in a region where other cultural aspects have many more significances than just working the land.

The results revealed the capacity of young farmers to understand their reality and acknowledge complex issues such as rural exodus, family succession and payment for ecosystem services. Even with a fifteen-minute explanation of conceptual model creation, they could represent their reality as a system, through a diversity of elements in several subsystems (political, environmental, social).

Although the approach was mainly focused on the inclusion of young farmers perspective, what put in check the claim of being participatory, it must be considered as the first stage of a broader interactive process of modeling. By this perspective, the model development has to be taken into account as an opened process without finish (Checkland, 1999). The intention is to make the model a recursive tool to be redesigned and refined constantly, especially because it represents a dynamic complex system in continuous transformation.

Our effort aimed to insert participants' perspective into a simulation model that we expect will help the farmers to deepen their understanding of their reality and assist them in making better-informed decisions when managing their properties. Through the next interactive and iterative stages, the model will be validated and refined, this time with adults and other stakeholders. We expect that the further steps will increase the model's robustness and promote informed discussion about the challenges and risks associated with possible future scenarios.

Furthermore, we plan to expand the model to insert some ecosystem services into its structure to better evaluate the potential environmental benefits related to the agroecological practices applied in the area. By this end, we intend to access if the practices are as beneficial to the environment as it appears to generate income.

We recognize that given the timescale of some ecosystem services (like some related to climatic events) makes the perception of changes difficult, preventing volunteering attitudes towards its maintenance. In this sense, we advocated the promotion of social learning activities (van den Belt, 2004) with youth as a way of building bottom-up initiatives seeking community empowerment, increasing the level to common global issues.

During next steps of the modeling journey the involvement of several other stakeholders is expected and the model can become a tool to assist the local government in evaluating and taking a better-informed decision of public policies to improve farmers' life and the ecosystem services related to their lands. Our contribution to the growing body of research in participatory modeling reinforces the importance of involving the youth in planning and decision-making arenas, since they are increasingly inserted in the "digital revolution" and must be encouraged to have a long-term perspective about the future.

Future studies should explore how CM and CLDs can be used to stimulate additional questions for modeling, including divergence in local cultural models, or variation due to gender or generational difference. Exploring different formats of workshop design, such as comparing workshops with and without parents' presence could bring interesting insights of how it can influence young participation.

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