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A CO-DESIGN METHODOLOGY TO RECONNECT CROP AND LIVESTOCK IN AGRICULTURAL SYSTEMS: FARM COACHING, SERIOUS GAMES AND ADVISORY ROLES ON THE DEVELOPMENT OF INNOVATIVE IDEAS

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Thesis submitted in fulfillment of the requirements for the degree of 'Doutor em Zootecnia", at 'Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul'.

Advisor: Prof. PhD. Paulo César de Faccio Carvalho

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UMA METODOLOGIA DE CO-DESIGN PARA RECONECTAR LAVOURA E PECUÁRIA EM SISTEMAS AGRÍCOLAS: FARM COACHING, JOGOS SÉRIOS E PAPÉIS DE CONSULTORIA SOBRE O DESENVOLVIMENTO DE IDEIAS INOVADORAS[1]

Autoria: Fernanda Gomes Moojen
Orientação: Paulo Cesar de Faccio Carvalho
RESUMO: O fenômeno mundial de especialização dos sistemas de produção levou a uma separação das lavouras e da pecuária em nível espacial. Consequentemente, efeitos colaterais têm sido relatados, como perda de biodiversidade, poluição da água e do ar e redução da qualidade do solo. Reconectar lavouras e pecuária seria uma ótima opção para limitar esses impactos e favorecer a agricultura sustentável, e, desta forma, reverter essa tendência de especialização. Os Sistema Integrados de Produção Agropecuária (SIPA) são sistemas complexos, desafiadores e diversos, cujos benefícios potenciais são alcançados apenas se as lavouras e os animais forem devidamente reintegrados. O planejamento espaço-temporal requer uma abordagem sistêmica, considerando o contexto solo-clima e às motivações dos agricultores. O objetivo deste estudo foi desenvolver uma metodologia para co-design de cenários para reintegrar de forma sustentável as lavouras e a pecuária em nível de fazenda. Após ter revisado as ferramentas existentes para redesenhar os sistemas lavoura-pecuária no nível da fazenda (Capítulo I), proponho primeiro, descrever os processos de construção de uma metodologia para aumentar a conscientização dos agricultores e partes interessadas sobre o interesse do SIPA para aspectos econômicos e ambientais e entender o acoplamento espaço-temporal como um forte componente de sua eficiência (iniciativa Farm Coaching (Capítulo II). Farm Coaching foi bem-sucedido em modificar o modus operandi dos agricultores, consequentemente promovendo uma abordagem de *co-design* para ICLS implementação. No capítulo III, desenvolvi um *serious game* para fomentar a percepção das partes interessadas sobre a concepção de SIPA, simular processos de decisão e as consequências das estratégias escolhidas. As sessões de jogo serviram como uma plataforma de troca de conhecimento, permitindo aos jogadores compreender a lógica das decisões do SIPA e seus impactos no desempenho global da fazenda. No capítulo IV, analisei como os conselheiros perceberam seu papel na condução de transições em direção a SIPA sustentáveis e exploraram as ferramentas que desenvolveram ou não tinham, examinando as experiências brasileira e francesa. Em conclusão, eu encorajo a expansão da metodologia e ferramentas desenvolvidas, uma vez que a combinação de ferramentas técnicas parecia relevante para projetar SIPA. Combinar a abordagem técnica ao apoio psicológico como Farm Coaching em transições sustentáveis pode ser personalizado em outros contextos agrícolas. Finalmente, as entrevistas revelaram barreiras e alavancas do SIPA em nível de campo. Nesse sentido, há uma enorme necessidade adaptar a formação de consultores de forma a melhor considerar os desafios e especificidades em SIPA em termos de conhecimento, habilidades e ferramentas. Esta tese é o primeiro passo para a concepção e implementação eficaz do SIPA na fazenda. Por fim, os próximos passos desta pesquisa serão apresentados no capítulo V desta tese.
Palavras-chave: Farm-design; SIPA; Transições de sustentabilidade; aprendizagem experiencial; pensamento sistêmico

[1] Tese de Doutorado em Zootecnia - Plantas Forrageiras, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil. (174 p.) Maio, 2021.

A CO-DESIGN METHODOLOGY TO RECONNECT CROP AND LIVESTOCK IN AGRICULTURAL SYSTEMS: FARM COACHING, SERIOUS GAMES AND ADVISORY ROLES ON THE DEVELOPMENT OF INNOVATIVE IDEAS[2]

Author: Fernanda Gomes Moojen
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ABSTRACT:
The worldwide phenomenon of production systems specialization has led to a separation of crops and livestock at the spatial level. Consequently, side-effects have been reported, such as loss of biodiversity, water and air pollution, and soil quality depletion. Reconnecting crops and livestock are a great option to limit these impacts and favors agricultural sustainability, thus reversing the specialization trend. Integrated Crop-Livestock Systems (ICLS) are complex, challenging, and diverse systems, in which potential benefits are achieved only if crops and livestock are properly recoupled. Such space-time design requires a systemic approach, considering soil-climatic contexts and farmer motivations. The objective of this study was to develop a methodology to co-design scenarios to sustainably recouple crops and livestock at the farm level. After having reviewed the existing tools to reconceive crop-livestock systems at the farm level (Chapter I), I propose first to, describe the building processes of a methodology to raise awareness of farmers and stakeholders on the interest of ICLS for economic and environmental aspects and II) understand the space-time coupling as a strong component of their efficiency (Farm Coaching initiative (Chapter II). Farm Coaching was successful in modifying the modus operandi of the farmers, consequently promoting a co-design approach toward ICLS implementation. In Chapter III, a game to foster stakeholders' perception of ICLS designing was developed, simulating the decision processes and the consequences of strategies chosen. The game sessions also served as a platform for exchanging knowledge, allowing players to understand the logic of ICLS decisions and their impacts on the farm's global performance. In Chapter IV it was analyzed how field advisors and project managers perceived their role in driving transitions toward a sustainable ICLS and reviewed the tools they developed and what was lacking to encourage transitions, in both Brazilian and French farms. In conclusion, I encourage out-scaling the methodology and tools developed, combining relevant technical tools to ICLS design. Combining technical approach to psychological support as Farm Coaching under sustainable transitions could be customized in other agricultural contexts. Finally, the interviews revealed barriers and levers of the ICLS on the field level. In this sense, there is a huge need to adapt advisor training to better consider challenges and specificities in ICLS in terms of knowledge, skills, and tools. This study is the first step towards designing and effectively implementing ICLS at the farm level. Next steps of this research will be presented in Chapter V.

Keywords: Farm-design; ICLS; sustainability transitions; experiential learning; system thinking

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TABLE OF CONTENTS

LIST OF TABLES

TABLES CHAPTER II

TABLES CHAPTER III

TABLES CHAPTER IV

LIST OF FIGURES

FIGURES CHAPTER I

FIGURES CHAPTER II

FIGURES CHAPTER III

FIGURES CHAPTER IV

LIST OF ABBREVIATIONS

ATP	Annual Tropical Pasture
AtP	Annual Temperate Pasture
CAP	Common Agricultural Policy
CUMA	Agricultural Material Exchange Cooperatives
FC	Farm Coaching
ICLS	Integrated Crop-Livestock Systems
NC	Number of Cities
ND	Not Available
NP	Number of Participants
PR	Paraná State
PTP	Perennial Tropical Pasture
RS	Rio Grande do Sul State
SIA	Serviço de Inteligência em Agronegócios
tPAF	Temperate Pasture After Rice
UAA	Usable Agricultural Area

CHAPTER I

1 INTRODUCTION

Integrated Crop-Livestock Systems (ICLS) are planned systems that involve the farm-design of temporal and spatial interactions of livestock and crop production to achieve synergies from the interactions that result in emergent properties (de Moraes et al., 2014). As the world has been moved towards the specialization of production systems, transitions to sustainable and integrated systems would need a farm re-design (Church et al., 2020; Garrett et al., 2020; Moraine et al., 2014a; Pissonnier et al., 2019; Romera et al., 2020).

In this context, participative design is one of the drive factors to promote the reemergence of ICLS (Garrett et al., 2020). Several co-design methodologies have been proposed in the literature, but little concern has been noted about what happens when the researcher stops leading the project (Lacombe et al., 2018). In this sense, it is important to connect researchers with advisors, as they play a direct role in scale-out research proposals and supporting farmers in on-farm implementation (Le Gal et al., 2011). Besides, the farmer-advisor relationship needs to be changed from a “prescriptive expert” to a “co-developing” role to engage farmers to face the emerging challenges as they transition towards sustainable ICLS (Nettle et al., 2018). Darnhofer et al. (2014) stated that transition to sustainability is context-dependent; therefore, it is not a homogeneous process. So, it is important to understand each farm system design and deal with the configuration of resources and farmers’ strategy (Martin et al., 2013).

Looking more in-depth at the tools and methods available for interaction between farmers, advisors and researchers, and the co-design of sustainable systems, serious games are a promising way as designed experiences where players can learn by doing (Jouan et al., 2020). Although, in general, serious games represent an abstraction and simplification of reality, they help players temporarily have distance from their routines and have a freedom space to reflecting, simulating and discuss long-term farm management and planning (Hertzog et al., 2014; Salvini et al., 2016). To deal with such a complex transition, advisory systems need to be more prepared for new roles of technological adaptations and co-design to bring innovation and sustainability in a rapidly changing world (Compagnone, 2011; Klerkx, 2020; Nettle et al., 2018).

In this way, I addressed **how to design a methodology to reconnect crops and livestock in agricultural systems** by analyzing the Farm Coaching initiative in southern Brazil. Besides, I proposed a **case study** of Brazil and France to look in-depth into how advisors perceive and manage their interactions in ICLS farms.

A literature review on the existing tools to re-design crop-livestock systems at the farm level and advising on the thematic of ICLS was summarized and shown in Chapter 2. Then, three studies will be presented: i) The Farm Coaching experience (Chapter 3) ii) the development and application of the serious game (Chapter 4) iii) advisors' perceptions integrated systems – from Brazil and France context (Chapter 5). The Final Chapter (6) brings the main conclusions, further developments, and personal remarks on the development of this thesis (Figure 1).

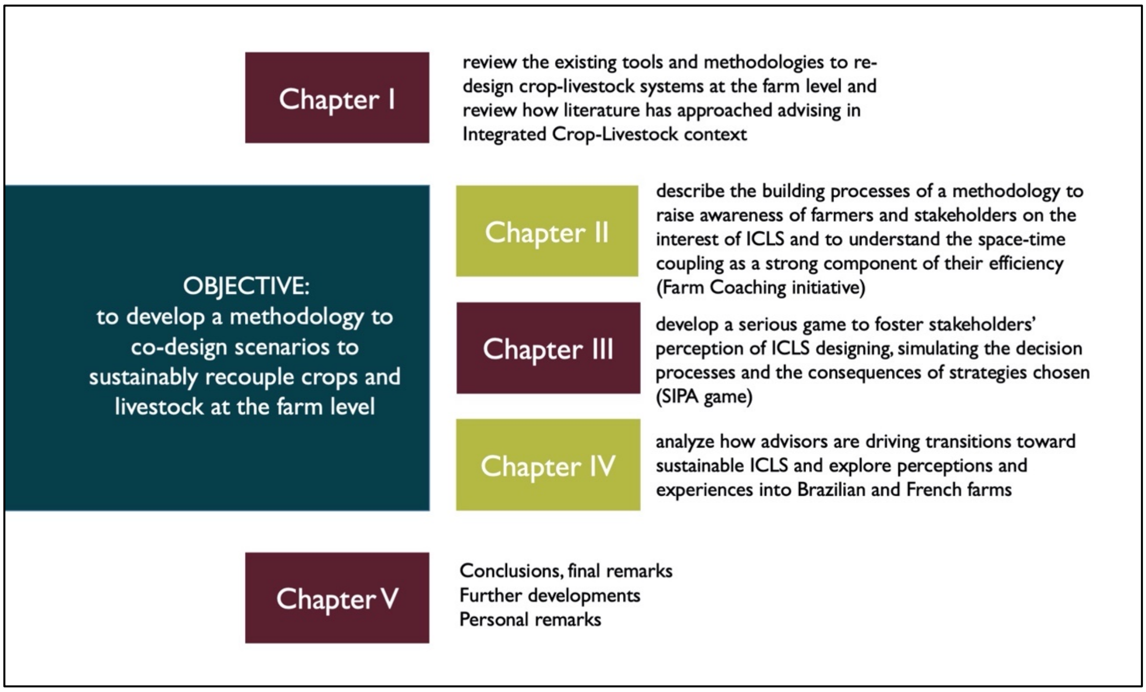

Figure 1. Scheme of presentation of this thesis

2 LITERATURE REVIEW

2.1 Farming Systems Research

The Farming Systems Research approach is a counterpoint to the conventional and formal top-down technology transfer models, as it aims to develop participative pathways towards more sustainable food production (Gibbon, 2012). The evolution of farming systems has an important influence of human interaction, learning, conflict resolution, agreements, and collective action. Thus, it is important to have an adaptative approach to consider the complexity and dynamics of these influencing factors (Darnhofer et al., 2012).

The core characteristics of Farming Systems Research are the use of systems thinking (capture the “logic” of the farming system and keeping the “bigger picture” always in mind), interdisciplinary methods, and a participatory approach (Darnhofer et al., 2012). Also, participatory methodologies have four important principles: systemic and group-learning processes, acceptance of stakeholders’ multiple perspectives, facilitation leading to transformation, and learning leading to sustained action (Gibbon, 2012).

This approach fits well in the co-design and diffusion of sustainable ICLS, where one of the presuppositions is precisely a deliberate intention of integration, different from simple crop rotation or simple income diversification (Carvalho et al., 2014). A successful ICLS improves synergistic relationship among the components (the whole is greater than the sum of the parts), and it results in enhanced social (including community), economic and environmental sustainability as well as it improves the livelihoods of those farmers who manage them (FAO, 2010)

2.2 Redesigning Farming Systems

A redesigned approach is necessary to transitions towards ICLS in a sustainable way. There are four major driving forces behind the need for redesign mostly of current farming systems: 1) environmental impact of agricultural practices, 2) increase in the demand for food, 3) availability of work and income of farmers, and 4) lack of territorial organization (Meynard et al., 2012). The authors also highlight that the redesign must bring a diversity of solutions considering different futures, helping farmers and stakeholders to build their systems based on their situation and making their own compromises to guarantee sustainability.

To redesign, we need first to look at how system design can be developed (Figure 2). The most common approach is the rule-based design, where a set of steps are developed as defined in advance in a linear way. On the other hand, there is an innovative design approach, which has more plasticity in the design and requires creativity as several implementation options are possible and mutual learning is encouraged (Meynard et al., 2012).

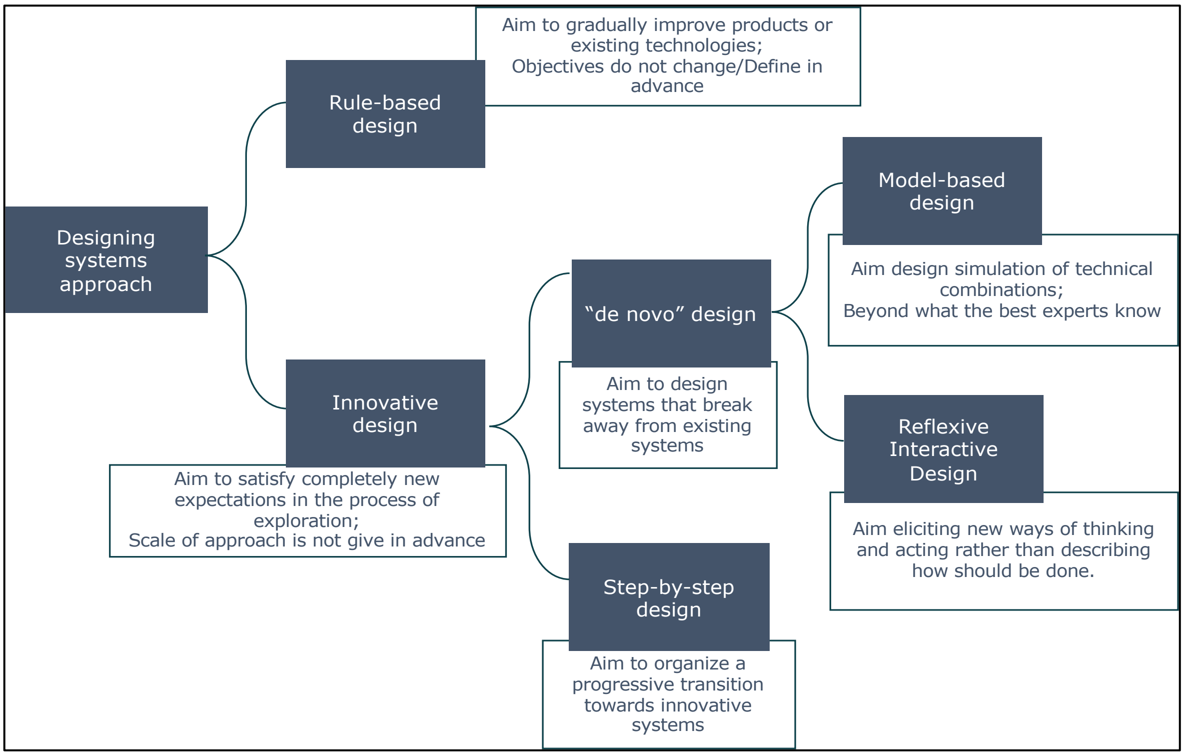

Figure 2. Systems design approaches: main categories and their aims. Adapted from Meynard et al. (2012).

Innovative design is a way to contribute to solving critical food production challenges worldwide (Le Gal et al., 2011). Within innovative design, there is also an important distinction between approaches: whether they break away ("de novo" design) or not (step-by-step design) from existing systems. The most common way to choose "de novo" is the model-based design, but this approach has the weakness of the need for complex variables and difficult terminology, so the validation is not easily achieved. Step-by-step design can look less sophisticated by academic standards but is the only approach that starts with a diagnosis, followed by jointly choosing innovation paths. These steps make a considerable difference in the acceptance of a proposed redesign (Meynard et al., 2012). In the second chapter of this thesis, a step-by-step design case of advising in southern Brazil will be presented.

2.3 SERIOUS GAME IN AGRICULTURAL CONTEXT

The current pandemic scenario of COVID-19 brought physical restrictions, including the use of physical learning tools. This scenario brings an opportunity for farmers to engage via games that can be customized to the online format (Hernandez-Aguilera et al., 2020). Games are composed of boundary objects (such as computational models or pieces) that are important for the understanding among the participants through a common vocabulary, an important point for the communication of the different actors: farmers, advisors and researchers (Martin, 2015).

One of the oldest games reported in the scientific literature is the Overgrazing Game - developed in 1984 that was changed to Grazing Game (Villamor and Badmos, 2016). In this game, the objective is to manage the herd to increase the production of the cows avoiding overgrazing and consequent desertification. The game was applied in Ghana and proved to be a platform for exchanging perceptions about climate-related challenges. Martin et al. (2011), proposed the first game-based approach for farming system design where farmers and extension services were involved. The game, called “forage rummy” consists of repeated cycles of livestock systems design adapted to scenarios of the agricultural production context and evaluation of their biophysical and organizational feasibility. The authors' effort to offer transparent and easily usable forms of support to the design process proves to be useful in stimulating discussion, reflective and interactive analysis and learning, their management, and the scope for their adaptation.

2.3.1 Role-playing games as learning experience for farmers, students, and advisors

Role-playing games are games where players are invited to take on temporary roles to reveal interdependencies between stakeholders (Moreau et al., 2018). In these types of games, players may be asked to assume roles like their own in real life or to exchange their roles with other participants. In this second case, the players "put themselves in the shoes of others" and thus better understand others´ difficulties and needs (Etienne, 2003). Four interesting examples are games with this format: i) SYLVOPAST, which proposes the establishment of a silvopastoral management plan between forest farmers and sheep farmers (Etienne, 2003); ii) SECOLOZ, on handling mountain farming systems, where farmers play the role of agents in a national park and agents as farmers (Moreau et al., 2018); iii) Role play in Climate Smart Agriculture, where farmers simulate scenarios for implementing agroforestry activities (Salvini et al., 2016); iv) FOWIS, where farmers and local authorities design scenarios for the use of water for irrigation of rice, sugar cane and vegetables (Hertzog et al., 2014).

The role-playing games bring an engaging narrative where the players´ roles are characterized, establishing an intrinsic motivation in a safe, collaborative and fantasy environment, necessary for the learning and development of critical thinking (Salvini et al., 2016). In chapter 3 of this thesis, we will show the SIPA game in which players are invited to assume the role of the farm's technical team (specifically, to play the role of consultant to the ICLS). The fact that the players have their roles defined initially means that in the presentation phase of each group of players, the ideas are defended, thus generating a fruitful debate with the researchers and advisors who participate in this final stage. It is also important to highlight an experience with SIPA game with undergraduate students in Brazil, where they assumed the role of owners of an advising company. Therefore, in addition to proposing an integrated production scenario to a farmer, they still need to think about how their service will function (online versus on-farm interaction, frequency throughout the year, activities included) and regarding the value of the project and the advising (i.e., how much it will cost). To this end, an advisor was invited to teach students how to format the advising proposition, and a farmer decided to hypothetically “hire” or not each consulting company, arguing the advantages and disadvantages perceived by him. This pedagogical potential of the game for training undergraduate students should be better explored and analyzed soon.

2.4 ADVISING IN INTEGRATED CROP-LIVESTOCK CONTEXT

Once ICLS is defined as a direction to be followed, the practical challenge is huge since it starts with a structural problem of i) research is commonly restricted to single commodity as meat, milk, soy and corn (Garrett et al., 2020), ii) agricultural courses do not develop enough system approaches and often fall into specialized disciplines disconnected from each other (Jouan et al., 2020), iii) tools have been developed for zootechnical controls vs. only agronomic controls, and iv) specialized nature of advisory sector (Garrett et al., 2020). The consequence is that few advisors are sensitized with ICLS and lack of support approaches for farmers in transitions.

Dockès et al, (2019), summarize the different methods of advice concerning the number of people involved and the role of advisors: i) individual advice, highly customized to the reality and expectations of each farmer and requires technical and economic skills from the advisor, as well as the ability to teach these techniques in addition to active listening; ii) group advice, where there are discussions between farmers and one or more consultants and requires mediation and facilitation skills from the consultant; iii) mass distribution: where there is a dissemination of results to a broad audience and requires skills such as writing technical bulletins, organizing a field day, presenting lectures from the advisor; finally, a combination of the previous items is possible in the form of iv) integrated advice where consultants need to be prepared to address complex issues on a variety of farms. An example of an ICLS extension program with integrated advice was conducted in Australia called Grain & Graze. In this extension program, less than half of the initial target of 6800 farms adopted new ICLS practices and they attributed the challenge of adoption to the fact that ICLS involves complex decisions, unlike programs that traditionally address commodity-by-commodity (Price et al., 2009).

2.5 CONCEPTUAL MODEL OF THE THESIS TO ENCOURAGE TRANSITION TOWARDS SUSTAINABLE ICLS

The agricultural phenomenon of specialization led to decoupling nutrient and energy cycles of crops and livestock at the spatial level (Garrett et al., 2020). Consequently, side-effects have been reported, such as loss of biodiversity, water and air pollution, and soil quality depletion. To face this situation, the Integrated Crop-Livestock Systems (ICLS) represents a potential alternative to improve sustainability by re-coupling soil crops and livestock (Bonaudo et al., 2014). Yet ICLS are more complex than specialized systems, and the potential benefits are achieved only if crops and livestock are properly recoupled. So, there is a need of relevant methods and tools to design ICLS (Moraine et al., 2014a), and to develop multi-actor and multi-domain approaches to achieve such a complex transition (Duru et al., 2015b).

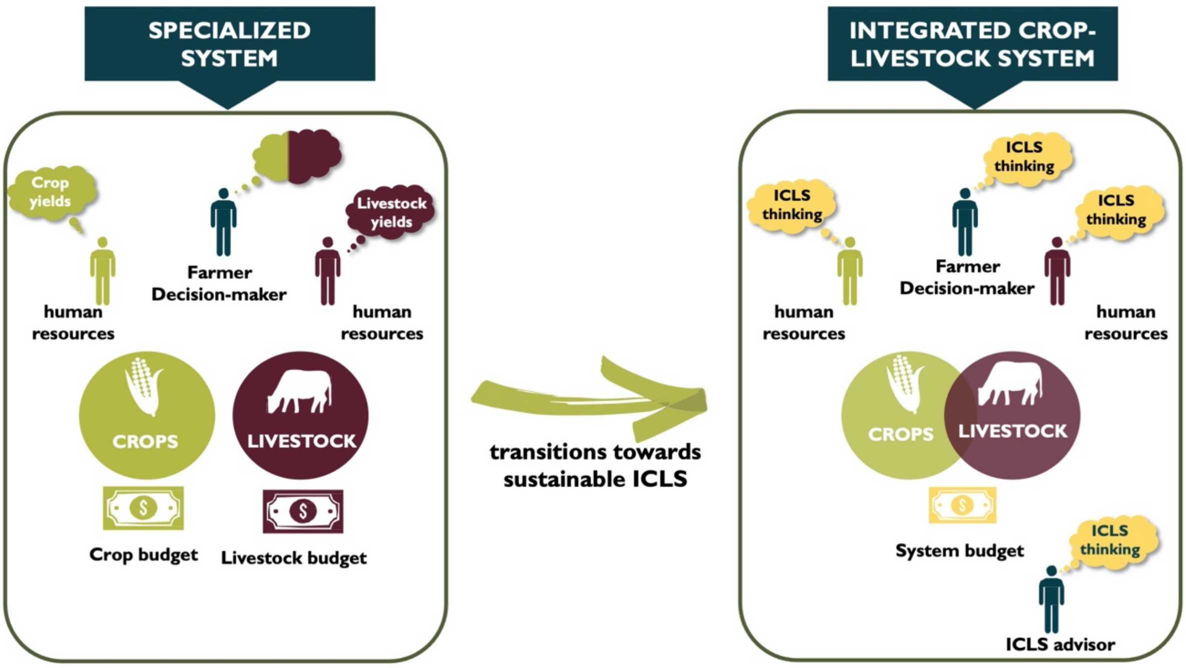

Figure 3. Conceptual model showing main components (crops, livestock, budget, and human resources) and their interactions in a specialized system and in an integrated crop-livestock system. The thought bubbles represent the mindset of the actors that changes in the transitions towards sustainable ICLS.

The main question of this thesis is to examine how to sustainably transition towards integrated systems. This question is an umbrella for three more specific ones that will be unfolded in each paper in the following chapters. The essence behind this issue comes from the disconnection of livestock and crop production and, consequently, the decoupling of biogeochemical cycles. On the left side of the conceptual map, it is possible to see crops separated from animal production and, consequently, isolated thoughts (Figure 3). In this scenario, the budget is separated, the use of human resources is segmented, and thus, decisions are segmented. This represents that specialized systems lead to a yield-centric approach, one of the agricultural paradigms where yields are target over whole-farm outcomes (Garrett et al., 2020).

The human resources in the specialized systems were represented as the group related to crop and other to livestock production. For example, the hiring of a veterinarian for animal health issues and an agronomist is hired to assist in the decisions of crop nutrition. This separation comes from the need for specialists in the subject, whose training fits the demand. In this example, each consultant goes to the farm to see only one component. As the budgets are separated, the components of crops and animal production receive a slice of the total budget and are compared in terms of profitability, which can create competition, and which is the best. Both are often kept on the farm only to diversify the source of income.

On the other hand, in the right part of the conceptual map, we have an integrated crop-livestock system scenario represented, where there is a spatiotemporal interaction of the system's components. This system requires design to explore the interactions and complementarities, as well as the resulting emergent properties. In this scenario, systemic thinking is mandatory, and the entire system will be the result sought. Obviously, there are needs of manpower and advising on issues intrinsic to livestock or crop production, but the search for solutions and performance should be thinking about the system in both cases. For example, the breeding season´s choice or the sowing date can be changed according to the greatest benefit for the system, which will not necessarily be in the optimum production of the isolated components. As new farming paradigms create new professional situations for advisors (Nettle et al., 2018), in ICLS scenario, a "new advisor" is needed, with the role of co-designer of the whole system.

The conceptual model also represents the presence of two other actors in this process: a) the owner (s) of the land and b) the decision-makers – who can be the owner himself (leading only the crops, only the cattle or both) or a lessee. In Brazil´s land structure, it is very common to have lessees or partners who only drive crops or cattle. In integrated systems, it is necessary that their management have synergy with the other component managed by the landowner as they will be sharing land use.

The second chapter of this thesis will address the mindset change, represented in the concept map as colored bubbles where green means livestock, burgundy means crop thinking, and yellow represents ICLS. The question addressed in this chapter is therefore represented in the central part of the conceptual map. In sequence, chapter 4 is related to the right side of the concept map. Once the mindset has been changed to integrated systems, it is necessary to adapt the farm design. In this sense, there is a serious game proposition for learning ICLS budgeting and planning. Finally, chapter 5 is linked to the system advisors represented in the concept map. To better understand their role, challenges and experiences of these system consultants, advisors who currently perform this role in Brazilian and French contexts were interviewed.

3 HYPOTHESIS

Farm Coaching workshop through four steps of mindset changing will guide a co-learning process, the co-design and implementation of sustainable ICLS by stimulating innovative farming systems thinking.

As ICLS are more difficult to plan and manage due to multiple interactions, than a specific serious game for co-designing scenarios would help farmers understand system planning.

Advisors drive transitions towards ICLS at the farm level with adapted tools and need more complex skills to deal with coupling crop and livestock production.

4 OBJECTIVES

Disseminate knowledge on sustainable integrated crop-livestock systems by a learning experience methodology. Specifically, by (i) depicting the development of the FC workshop; (ii) describing farmers' interviews, illustrating the changed mindsets after learning and practicing systems thinking; and (iii) describing concrete actions that farmers need to develop on the farm supported by specialized ICLS advising.

Develop, validate, and improve a holistic and simplified game to design concrete scenarios for reintegrating crops and livestock at the farm level. Aiming to (i) depict the development of the game as a method to foster holistic ICLS design; (ii) illustrate game outputs, and (iii) describe farmers' interviews with their impressions and learnings by the game.

Assess the advisor's perceptions of levers and barriers for the transition towards sustainable ICLS. Looking at (i) similarities and differences between the Brazilian and French context; (ii) mobilized knowledge, source of information, motivations, and objectives of advisors and (iii) tools, methods and projects that are being used by advisors and project managers in integrated systems.

CHAPTER II

THE FARM COACHING EXPERIENCE TO SUPPORT THE TRANSITION TO INTEGRATED CROP–LIVESTOCK SYSTEMS: FROM GAMING TO ACTION

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Abstract

CONTEXT

Integrated crop–livestock systems (ICLS) are supposed to achieve eco-efficiency while accomplishing the global agenda of the future food demand. Still, ICLS are more complex to manage than specialized systems, thereby posing a challenge for researchers, farmers, and advisors to develop coordinated actions.

OBJECTIVE

Farm Coaching (FC) was developed to allow farmers to understand and manage the complexity in ICLS toward sustainable ICLS implementation.

METHODS

The initiative was led by the advisory company SIA (Serviço de Inteligência em Agronegócios) together with ICLS researchers. Farm Coaching was developed based on a workshop to integrate the concepts of agricultural management (i.e., soil, plant, animal, and financial resources) and personal coaching (i.e., assertive communication and time management). During each workshop, four steps are proposed: 1) deconstructing the current modus operandi, 2) going through concepts and tools to understand ICLS, 3) experience through re-conception, and 4) co-designing both a new lifestyle and production system. Step three consists of a serious game session where participants create an ICLS farm-design by space–time coordination between crops and livestock. To better understand the impacts of FC a participant observation and individual interviews were conducted with 12 farmers.

RESULTS AND CONCLUSIONS

Four FC editions were held between 2017–2019 (90 participants in total). The 12 farmers interviewed also experienced specialized ICLS advisory besides the FC to help set up the concepts of sustainable ICLS, including whole farm design and transition into practice. SIA company led the advisory that consists of a pre-set framework including diagnosis, co-design, and implementation. The results highlight the individual trajectories of implementing ICLS projects. Initial strategies reported to transitions included: implementing pilot projects, evaluating technical and financial indicators, organizing personal working routines, improving teamwork skills to deal with the new concept duties, and having personal coaching sessions some farmers have demanded due to realistic and strategic issues.

SIGNIFICANCE

The FC initiative successfully modified the farmer´s *modus operandi*, consequently promoting a co-design approach toward ICLS implementation. Its original technical–personal blending approach, as well as how it deals with the psychological barriers to ICLS adoption, established the initiative´s novelty. Furthermore, it inspires the revision of current trends (i.e., specialized agricultural systems) and motivates the participants to act differently.

Keywords

Agricultural extension; Co-conception; Farm design; Mixed crop–livestock system; Sustainability transitions; Social-ecological system

1 Introduction

Integrated crop–livestock systems (ICLS) are a way to achieve eco-efficiency, i.e., the efficient and sustainable use of resources (Wilkins, 2008). Nonetheless, relative to specialized systems, ICLS entail more complexity in their planning and implementation. Specialized systems involve the standardization of production techniques and the search for economies of scale that engender the homogenization of crop and livestock breeds in rural landscapes (Moraine, 2014).

ICLS denote beyond simple crop rotations or income diversification, especially as one of its presuppositions precisely implies the deliberate intentions of integration to explore the synergistic effects resulting from its conception (Carvalho et al., 2014). Thus, despite the numerous benefits of ICLS, the complexity of such systems could constrain their adoption (Rousselle, 2007), resulting in the contemporary crop and livestock spatial decoupling, hence necessitating the need to seek levers to encourage their reintegration (Garrett et al., 2020).

In this context, adapting and transitioning to new techniques pose a challenge for advisors to support farmers (Le Gal et al., 2011). Since the prevailing research and advising is around agricultural crops or animal production in isolation, an ICLS approach is lacking (Garrett et al., 2020). Besides, in such an innovative scenario, advising not only represents a technical issue (Compagnone, 2011), but also includes knowledge on financing, human resource management, succession planning, and human expectations. Klerkx (2020) mentions the "development of farmer coaches" as a new agenda for extension research. However, this new vision assumes the co-construction nature of advising while recognizing the farmer´s cognitive autonomy (Lémery, 2006). Hence, advisory roles will need to change from a "prescriptive expert" type to a co-developer one, and new advisory practices and professional identities will have to be developed (Nettle et al., 2018). Therefore, a rich dialogue and a quality co-learning experience among researchers, farmers, and advisors are imperative in this process (Ryschawy et al., 2014) to ensure the social relevance, validity, and actionability of research outcomes (Barreteau et al., 2010). Accordingly, simulation (e.g., serious gaming) or modeling (e.g., companion modeling [ComMod]) approaches can be implemented with stakeholders to foster reflexive and interactive analyses (Le Gal et al., 2013; Voinov and Bousquet, 2010; Daré et al., 2009).

This study addresses the following question: How can we raise awareness of farmers and stakeholders and help them to understand and manage the complexity in ICLS to set up the first steps of sustainable transitions? Our hypothesis focused on a "Farm Coaching" (FC) workshop to guide a co-learning process, the co-design and implementation of sustainable ICLS by stimulating innovative farming systems thinking. Accordingly, the objectives of this study include: (i) to present the development of the FC workshop; (ii) to describe farmers' interviews, illustrating the changed mindsets after learning and practicing systems thinking; and (iii) to describe concrete actions that farmers need to develop on the farm subsequent to the FC, supported with specialized ICLS advising.

2 Material and method

2.1 Study context

Serviço de Inteligência em Agronegócio (SIA) is a private advisory company that has been operating in southern Brazil since 2010 and is connected to public universities through Aliança SIPA (ICLS Alliance), which is a public-private alliance to promote ICLS. It is led by: i) the Research Group on ICLS of the Federal University of Rio Grande do Sul; 2) the Agricultural Technology Innovation Center of the Federal University of Paraná; and 3) the Research Group on Innovation in Pure and Integrated Agricultural Production Systems at the Federal University of Rondonópolis.

This consortium has been conducting on-farm projects oriented toward small family farms with founding institutions and local partners (Paladini, 2017; Vieira, 2015). The ICLS has been proposed as one of the main technical pillars for a holistic approach, whereby sustainable intensification concepts are blended with agroecology (Mockshell and Kamanda, 2018). SIA advisors are entrusted with the duty of applying these technical pillars in the field, and after experiencing the ICLS advising in more than a thousand farms, they reported the challenges confronting ICLS implementation, which inspired the FC initiative. Some of these challenges included: (i) how to explain to farmers the long-term and intangible benefits of ICLS; (ii) how to present the complexity of integrating crop and livestock activities since land-use, workload, and financial resources entail space–time interactions, and how to do so without provoking aversions to the concept; (iii) the need to reach all the people involved (farm workers, owners families, stakeholders, etc, - not only owners) when diagonosing, designing and implementing the system; (iv) how to inspire a new mindset focused on long-term resilience and to change the logic of the short-term high productivity of specialized systems.

The FC initiative started in 2017, with the hypothesis that the defiance of ICLS adoption was not only technical but also behavioral (*sensu* human psyche). To design the FC structure, a psychologist from SIA, together with a group of SIA advisors and researchers from the Aliança SIPA, were asked to develop such format. The first outcome was a workshop aimed at connecting technical and personal development.

The transition towards the ICLS proposed here is a long-term process. There are three phases in which SIA-farmer interactions occur: i) kick-off with farmers contacting SIA; ii) a sensitization phase (FC, 2-4 days) with four iterative steps toward mindset changing; iii) and an on-farm advisory process with three main steps for transition to ICLS (Figure 1). In some cases, FC preceded the beginning of the on-farm SIA advising as it is proposed in the figure, or in some cases, the advising was already underway when farmers participated.

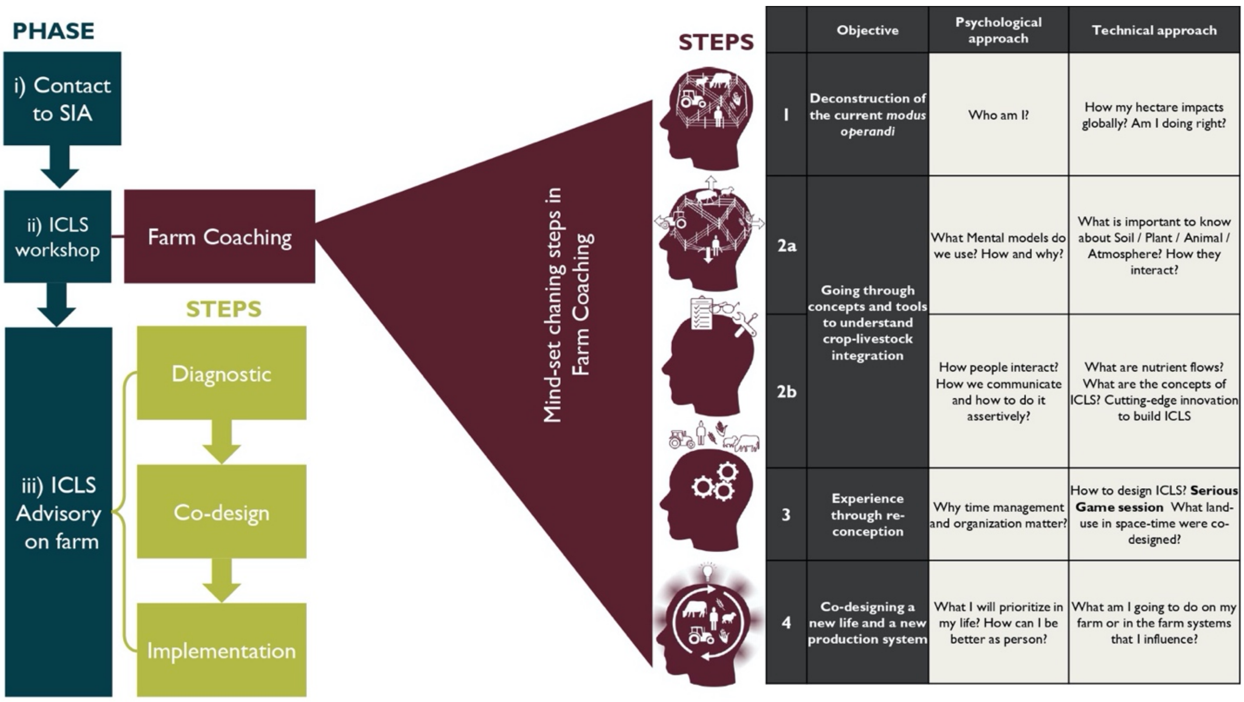

Figure 1. The sequence of phases and steps proposed for the transition toward sustainable Integrated Crop-Livestock Systems. On the left are the three mains phases (I, ii, and iii).

On the right, there is a zoom-in the sequence of learning steps during FC and the respective technical and psychological approaches.

2.2 Framework for analysis

The framework for analyzing FC as a transition approach to sustainable ICLS was based on a qualitative analysis through participant observation and inductive content analysis of interviews (Figure 2). Participant observation was carried out by five of the authors of this study, who were involved in choosing the concepts to be addressed, developing the sequence of FC steps, and applying the methodology during the workshops. Their perceptions and findings were shared between the authors and the other coaches after each workshop with a feedback from the participants of each workshop to help in the analysis. Besides, as two of the authors were advisors responsible for post-FC work with eight of the twelve interviewed farmers, they contributed with participant observation of real on-farm transitions.

We performed the inductive content analysis method with the whole manifest content of interviews by coding and grouping key themes emerging from it (Elo and Kyngäs, 2008). We grouped the emerging themes into six sub-categories: knowledge exchange, the workshop, the serious game, the on-farm advisory process, the ICLS constraints, and the results achieved.

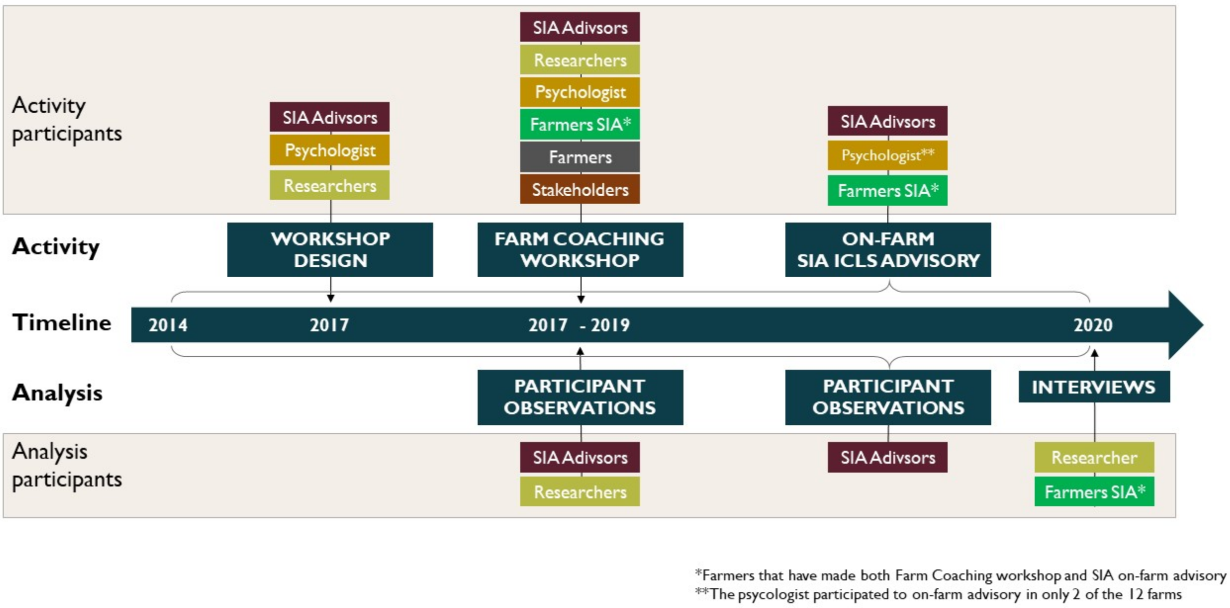

Figure 2. The framework for analysis of the FC workshops and on-farm SIA advisory. All participants' roles in the activities are described above the timeline. Below the timeline are the participants involved in the analysis of this study.

2.3 The Farm Coaching workshop

A four-step learning sequence is structured to combine "farming" and "coaching" in a single workshop. The rationale is presented in Figure 1, starting with a deconstruction of the contemporary *modus operandi* (step 1), followed by reviewing concepts and tools (step 2), gaining experience through re-conception (step 3), and finally, re-planning both the production system and the personal purpose (step 4). The workshop is structured for having both coaching and farming aspects that are connected in each step. Each edition is designed to be conducted with approximately 24 participants, and it lasts three days.

As a participatory approach, it is important breaking the ice among the participants in order to introduce an informal environment and to unravel for participants the questions that participants of a new group are persuaded to themselves, such as: "Who are the others?," "will they accept me?," and "what do we do?" (Etienne, 2015). To do that, the psychologist conduct a dynamic for each one introduces themselves to other participants before the workshops start.

Step 1: Understanding the limits of specialization: Deconstructing the existing *modus operandi*

The first step lasts 4-6h and aims deconstructing the existing modus operandi of specialization. This step consists of lectures and dynamics carried by the psychologist and a senior researcher. In this step we explore self-knowledge features from the initial profile (forms filled before the workshop) to address awareness about aspects of participants own life. The coaching techniques applied are based on self-knowledge (O'Connor and Seymour, 1990), where the universe of each person and everything around them is worked on, as well as the multiplicity of "selves" that exists in each person. The coaching techniques help participants reach internal congruence about their professional objectives and from that, find strength and personal power for the accomplishment.

The first step of FC also aims to make the participants understand the connection between planet Earth and their rural landscape. The participants are presented with notions of how anthropic actions impact local agricultural ecosystems at landscape and global scale and raise participants' awareness of the responsibility as a landscape user.

Step 2: Going through concepts and tools: Understanding crop–livestock integration

The second step lasts 4-6h and it is a review of the different compartments of agricultural systems (soil, plant, animal, atmosphere, and persons), and how they are interconnected. The participants are divided into two sub-groups and proceed to "thematic stations" (analogous to field days) that Aliança SIPA researchers and SIA advisors lead. Each station is placed in a separate room and is prepared to illustrate the theme. For example, soil monoliths, fertilizer samples, and forage samples are employed to explain concepts, while the soil station focuses on the physical, chemical, and biological attributes, as well as explains the differences and similarities of various production environments to clarify at what level these particularities respond to natural or anthropic decisions and actions. The pasture station is based on pastures and grazing animals. A new management concept, referred to as "Rotatinuous" stocking, as well as its cascade impact over the agricultural systems is presented (Carvalho, 2013; Savian et al., 2018). Grazing management is usually the limitation of the ICLS (Carvalho et al., 2010), and shortcomings influence the whole system via the soil compartment.

After soil, plant and animal being addressed there is a station to connect the compartments; the rationale of nutrient flows, and how to organize spatial-temporal succeeding crops that benefit this connection. The concept of system-level fertilization is presented (Faria et al., 2021), which is based on nutrient cycling on crop rotations to achieve nutrient-use efficiency, reduce nutrient input requirements, avoid losses and pollution, and maintain long-term soil fertility (Bernardon et al., 2020). The ICLS begins to be holistically viewed at this stage, especially from an ecological perspective.

The last "station" is the human compartment of the ICLS. Here, there is a psychological session oriented to help participants reflect in how to change behaviors and be better prepared to communicate their wishes. So, a debate is proposed to adress the reasons behind human behaviors. For conducting the debate, the psychologist present the methodology of neuro-linguistic programming (Bandler and Grinder, 1982). The methodology is based on the study of the relationship between mind and verbal/non-verbal language and the way people interact with the world and perceive its structure and relationships. A psychologist also explores the "mental models," seeking solutions and results in the personal and professional environment, focusing on "how" and "why." Besides, it is addressed with assertive communication (Marchiori, 2011) that considers the clarity of the information being transmitted, the underlying intentions, the respect for others, the context, and the social intelligence, all which hinge on the success of transitions put into action.

Steps 3 and 4: Experience the concepts: Reconceiving and planning

Step 3 lasts 4h and is designed to practice ICLS concepts in a serious game session. The psychological approach in this session is based on time management; the ability to make choices between important tasks, urgent tasks, and circumstantial tasks; and to avoid "the lack of time apology" as an excuse for the choices made and lack of planning and prioritization (Barbosa, 2012). While step 4 involves the reviewing of the FC experience globally, harmonize, and organize the next steps to record how they intend to undertake their actions in the coming months. In this step, emotional intelligence is also addressed, which consists of the ability to identify one's own feelings and those of others; to better manage emotions, self-control, and relationships through social dexterity; and to establish trust and engagement in teamwork (Goleman, 2001; Gardenswart et al., 2012). It is conceived to empower the participants to transition from "willing to do it" to "knowing how to do it" by combining elements of technical and personal coaching to move forward.

2.3.1 ICLS serious game session

The game is prototyped to be a holistic planning tool providing a quick view of the impact of various ICLS space–time arrangements. With a pedagogical function, it focuses on enhancing participants´ systems thinking. As in the crop-livestock farm simulator – named CLIFS, the whole-farm model automatically quantifies the effects of decisions (Ryschawy et al., 2014; Le Gal et al., 2011). The SIA advisors proposed the farm scenario as being analogous to what they face in farms. The design of the game focuses on a few parameters to diminish the "black box" effect and achieve legitimacy with stakeholders (Barreteau et al., 2001). The emphasis lies on the process, rather than the product (Voinov and Bousquet, 2010). Since the first FC edition, the game has been improved via single-loop learning (i.e., incremental improvement), as well as double-loop learning (i.e., changes in how practices are evaluated) (Argyris and Schon, 1996).

The game session has three stages a) group co-design, b) groups presentation, and c) system discussion (Figure 2). At the beginning of the session, participants are split into four groups of approximately six persons in separate rooms. The groups are preset by profile analysis to promote diversity and prevent the concentration of gender, relatives, workmates, previous professional experiences, municipalities, generation, and education level. Thus, in the first stage, the groups have one computer to access the Microsoft Excel® model that runs the game. They receive instructions including steps, rules, and goals. The available budget and carrying capacity parameters, which the SIA advisors stated and that are representative of actual field constraints, are used to challenge the planning. Cash crops are chosen to correspond to those used in southern Brazil, i.e., soybean, corn, wheat, rice, and beans (CONAB, 2020). Native grasslands and sown pastures complement the available alternatives to design an ICLS that simulates a farm of 1000 ha. During the co-design, advisors facilitate some group interactions with the participants, although with minimal direct interferences in their decisions.

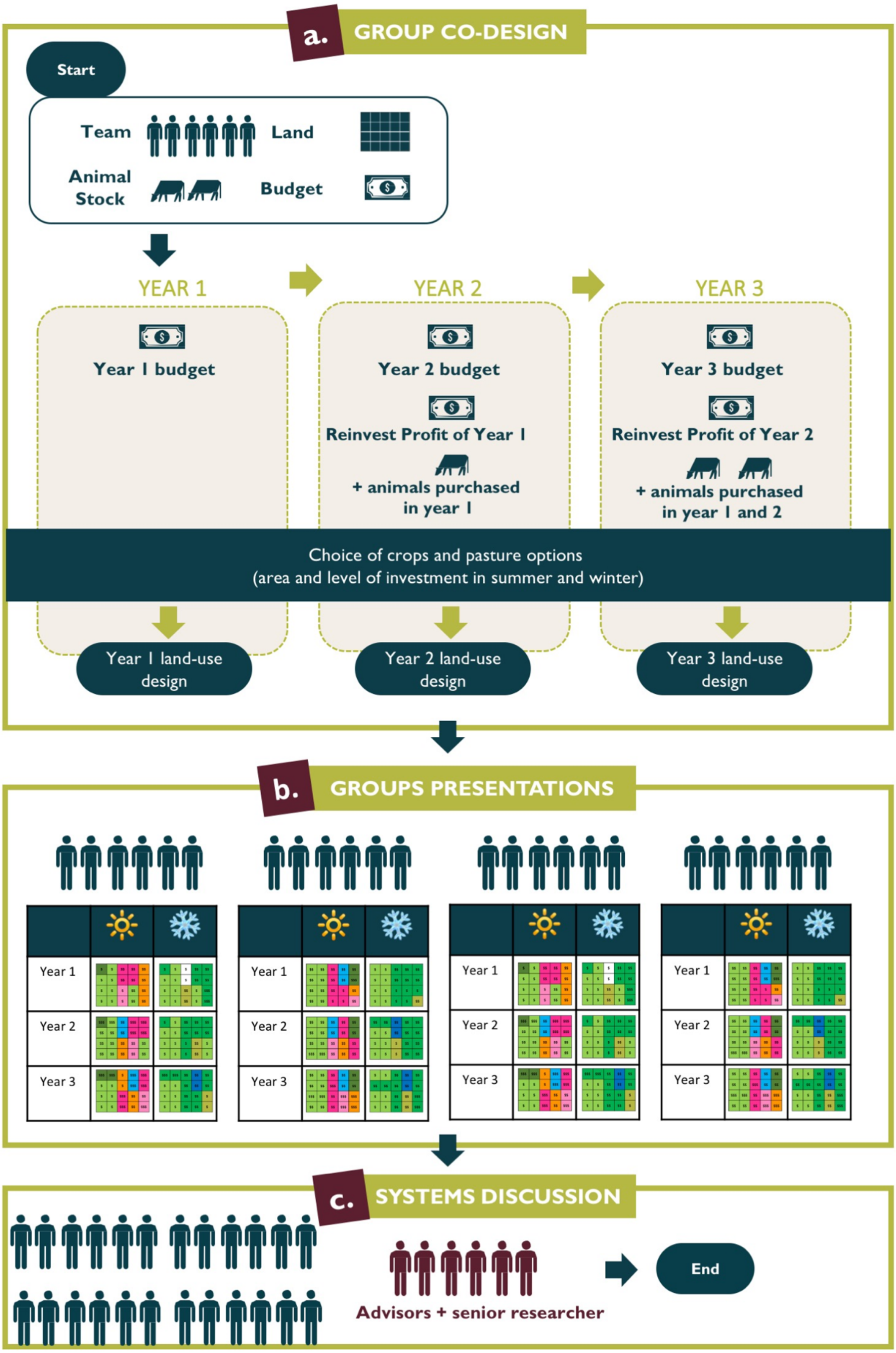

Figure 3. The representation of one game session, including a) one group's co-design, b) group presentations, and c) systems discussions.

Following the group co-design, the second stage is where all the participants are assembled to present and explain their proposal of land use (spatial design) and system evolution (temporal design) (Figures 3 and 4). At this stage, participants can recount the difficulties faced, how each team organized their time, and how they made decisions during co-design. After presentations, the third stage begins in which the senior researcher provides an overview of the proposals- vulnerabilities and otherwise, specifying the different farming strategies designed by the different groups (Figure 3).

Figure 4. Serious game in the fourth Farm Coaching edition. Pictures a) and b) are from two different groups during the co-design stage. Pictures c) and d) are groups presenting their systems during the groups presentations stage.

2.4 ICLS advisory service

The advisory service work was composed of diagnosis, co-design, and implementation. This work was developed with field visits (the advisors went to each farm according to a pre-determined frequency related to each contracting format) and interactions via phone calls and online chat. Besides, after FC some farmers chose to have a follow-up from the company's psychologist. Both technical advising and psychological accompanying are complementarity experiences that are important for farmer working with ICLS since several areas are directly connected and interact in space and time.

Although only one advisor was assigned to each farm, the SIA company values joint work between advisors to complement each other´s work. For this purpose, the company's advisors have training in complementary areas: agronomy, veterinary, animal science, and forestry engineering. This range of training is essential for consulting on integrated systems. Furthermore, in terms of sharing information and knowledge among advisors, periodic training is carried out in addition to daily contact through digital communication tools where, for example, a veterinarian who is in doubt about planting trees in the system can consult with agronomists and forest engineers. Another example to illustrate these exchanges, is if there is a need to build a health calendar for cattle on a farm, the agronomist will use his veterinary colleagues to develop it.

Finally, another company´s particularities is that SIA advisors mostly graduate in the Animal Science Research Program from the Federal University of Rio Grande do Sul, many of whom were colleagues, which is why they met and followed their careers together. By sharing the same vision of agriculture (sustainable intensification, integrated systems, sound pasture management, holistic approach) and strong connection with research during their formation, they managed to create a unique cohesion of technical principles in the Brazilian advisory context.

2.5 Interviews

To analyze the effect of the FC workshops on the actions put into practice afterward, we conducted 12 semi-directive interviews with the participants. To do so, we asked SIA advisors' help in contacting only farmers with ICLS who participated in FC and had SIA advising, in addition to sampling on diversity of farmer profiles to gain more insights in different points of view (Table 1). The farmers were coded with "F#" to guarantee their anonymity.

Table 4. Farmers interviewed in 2020 who participated in Farm Coaching workshops and had on-farm SIA advising. (UAA: usable agricultural area (hectares); FC edition: Farm Coaching workshop that each farmer participated in; RS: Rio Grande do Sul State; PR: Paraná State; M: male; and F: female.)

Farmer	Age	Gender	Farm Location	UAA	Farming System		FC edition	SIA advising since
					Crop	Livestock		
F1	43	M	Western PR	1,100	Soybean and corn	Beef cattle	1st	April 2018
F2	49	M	Southern RS	4,500	Soybean and rice	Beef cattle	1st	March 2018
F3	33	M	Western PR	910	Soybean, corn, and wheat	Beef cattle	3rd	April 2018
F4	34	M	Western PR	307	Soybean and corn	Beef cattle	3rd	July 2018
F5	29	F	Southern RS	2,758	Soybean and rice	Beef cattle and sheep	1st	April 2016
F6	66	M	Southern RS	4,510	Soybean	Beef cattle	1st	March 2018*
F7	42	M	Western RS	4,000	Soybean and rice	Beef cattle and sheep	1st	September 2017
F8	38	F	Western PR	45	-	Beef cattle	4th	October 2018
F9	47	M	Northern RS	1,020	Soybean	Beef cattle and sheep	4th	September 2015
F10	48	M	Northern RS	500	Soybean and oats	Beef cattle	1st	September 2015
F11	35	M	Western RS	347	-	Beef cattle and rearing of dairy heifers	1st	March 2014*
F12	60	M	Southern RS	655	Soybean, corn, and oats	Beef cattle	4th	October 2019*

*Discontinued at the time of the interview for personal reasons

The interviews were made in a cold way interviews (Piquet et al., 2013), which means they only took place between February and May 2020 to determine on-farm results from the FC experience. The interviews have proceeded in videoconferences individually (same interviewer + each farmer) and followed a formatted protocol: they were recorded, transcribed, and translated into English. The guide addressed: (i) farmers' main remarks on FC, (ii) their farming system pre- and post-FC, (iii) plans for the farm, (iv) the advisors´ roles, and (v) the results already accomplished. The interviews aimed to understand how the transitions occurred; excerpts will be presented in the following sections to illustrate the results and assist in the discussion.

3 Results

3.1 Farm Coaching workshops

Four workshops with a total of 90 participants were conducted between 2017 and 2019, attracting people from Brazil and Paraguay (Table 2). Participants were predominantly farmers (n=61), while the 29 others included 15 advisors, 6 project managers, 3 farm managers, 3 students, and 2 agricultural sales representatives. Their average age was 38 y (ranging from 21–75 y) and 41% were women.

Table 5. Participants from each Farm Coaching edition. Number of participants (NP), number of cities where participants live (NC), age, gender, and role of participants. *3 students, 6 project managers, 15 advisors, 3 farm managers, and 2 technical representatives

FC edition	Year	NP	NC	Age			Gender		Role	
				Mean	St. Dev.	Range	Female	Male	Farmers	Others*
1st	2017	22	17	37	±10	21–64	8	14	17	5
2nd	2018	20	15	36	±9	22–56	16	4	12	8
3rd	2019	24	14	41	±12	26–75	8	16	19	5
4th	2019	24	18	39	±12	24–60	5	19	13	11
	Total:	90		38	±11	21–75	37	53	61	29

The coaches of each FC edition were a) one psychologist trained in FC by the Brazilian Institute of Coaching and who participated in all four editions; b) one SIA advisor with a post-doc in ICLS who participated in all editions, plus one SIA advisor with a master's degree in ICLS who participated in three editions, and 1–2 invited advisors per edition; and c) 2–4 researchers from Aliança SIPA. In addition to the coaches, 3–5 people from the SIA team were present to help conduct the workshops. We highlighted that the results presented in this paper comes from a great alignment between all coaches in addition to training in ICLS and the presence of a psychologist with training in coaching. However, it is important to highlight that between each edition of the FC, several improvements were made, as new versions of the serious game were created and the decrease from nine coaches in the first two editions to five coaches in the last two, which gave more time for interaction with each coach, thus making the schedule less tiring.

The fist main result of FC is that it created a sharing space for farmers, stakeholders, advisors, and researchers interact together in ICLS thematic. Researchers and advisors provided the technical knowledge during the workshop, advisors also supported on-farm transitions (we will further describe it at 3.3 section).

3.2 A focus on step 3 of the Farm Coaching: Serious game session

During each game session players experienced using the concepts addressed in steps 1 and 2, such as: 1) system thinking - as in the game they designed the space-time land use of entire system (crops and livestock production) connected; 2) time management – as they had limited time to discuss and design the ICLS; 3) assertive communication – as they had to debate with other players to decide how to design; 4) ICLS – as they needed to address crop-rotations, crop-livestock system budget.

3.2.1 Game session example of outputs

To illustrate the outputs from the game, we present the results of two groups that participated in the fourth FC edition (Figure 5). Notably, both groups finished the third year with a gross margin of 200 USD/hectare (ha) (1 dollar = 4 reais, Jan 2020), using resource allocation strategies.

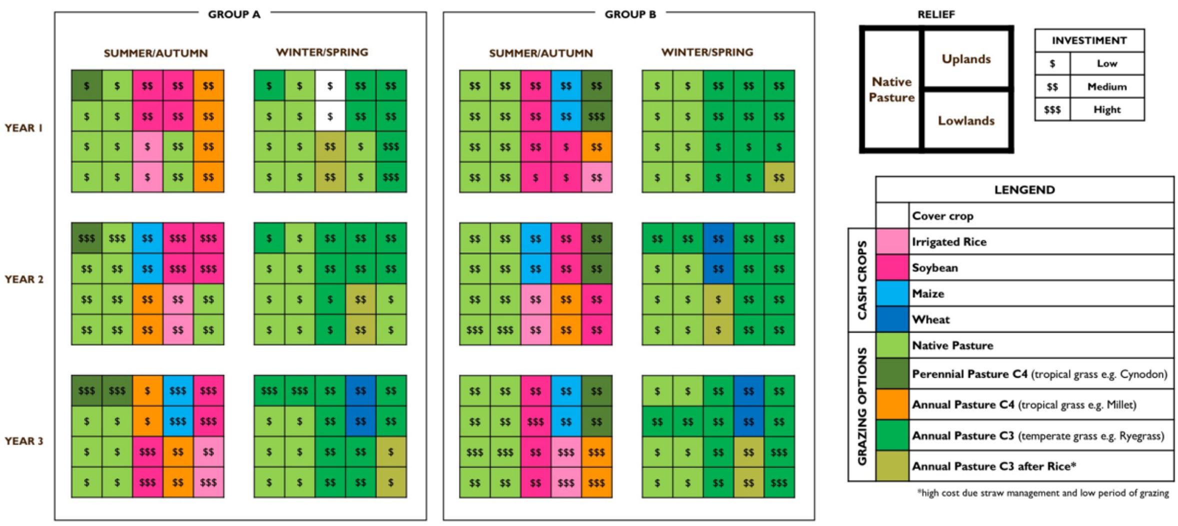

Figure 5. Example of land-use planning of an integrated crop-livestock system two groups co-designed in the fourth edition of Farm Coaching. The farm is represented in summer/autumn (left-hand column), and winter/spring (right-hand column). The year is represented in the horizontal strip (3 years). Each square represents 50 hectares located as the relief distribution (400, 300, and 300 hectares of native pasture, uplands, and lowlands, respectively).

Group A maintained 300 ha as native grasslands and planned the establishment of a perennial tropical pasture on 100 ha, plus an annual temperate pasture to increase the carrying capacity. In the uplands, they proposed rotating pasture, corn, and soybean. In the first winter, 100 ha of cover crops was used, and the annual temperate pasture in the remaining area. In the third year, their system was diversified by introducing 100 ha of wheat. In the lowlands, group A rotated in three parts, with 100 ha of rice being grown every year in a different place, thereby increasing investments on this crop over the years. In the remaining area, the annual and native pastures were used in the first two years. Soybean was introduced in the third year. In winter, the group proposed the entire area with pastures.

Group B did not change the land use of the 400 ha native grasslands. The group proposed highlands as 100 ha of perennial pasture and 200 ha with a crop–maize rotation, mainly followed by the annual pasture. In the second and third years, they added wheat. In the lowlands, they started with less rice, but with 100 ha in the second and third years, the same as group A. All the groups started with 1,000 animals, and they had different strategies for livestock planning. Group A purchased 30, 38, and 129 animals in the first, second, and third years, respectively, totaling an increase of 188 animals. Group B purchased 111 and 189 animals in the second and third years, respectively. Employing different strategies, group B´s livestock increased by 30% from initial herd. Overall, both groups discussed the results estimated by the worksheet of their chosen rotations; thus, providing a first entry into the systemic concepts of ICLS farming was significant.

3.2.2 Farmers' viewpoint of ICLS serious game in the workshop and connection to real-life

Farmers appreciated the FC serious game. Farmer 2 (F2) stated, "*It opened up a new possibility of business thinking, opened up a new path in my mind for a dynamic farm concept.*" Similarly, F3 disclosed that "*The strategy of the game is to put a bug on you- so that the farmer can see that it [ICLS] has to be addressed, it goes beyond merely going into an autopilot mode and replicating what everyone is doing; you have to think outside the box.*"

Participant F4 highlighted the diversification: "*The game gave us a vision that we could have other crops and investments with less risk, not only soybean-soybean-soybean; crop rotation is essential.*" Furthermore, F12 notice the game´s importance as a practical exercise: "*The game helped to realize what I was understanding from the workshop. So that was important, visualization and practice, actually!*" Contextually, F8 connected the experience to his on-farm reality about forage balance as he pointed out that, "*It was a group that was half crop farmers and half livestock farmers, and it was difficult to generalize on the livestock farmer's ideas that; Wait! There is no point in putting 100 cattle here if pasture supply will be insufficient.*"

As the initial scenario proposed in the game, F1 pointed out the disparity between investment in crops and livestock: "*Livestock's response is better and safer than crops. Crops have nothing to expand, while livestock is capable to develop, as it remains in a* *transformation process.*" By taking care of the whole system and looking at its results, F7 stated that, "*Our interest in livestock has been revitalized.*"

3.3 Emerging transitions on-farm with specialized ICLS advice after the FC workshop

Motivated by the FC workshop, some farmers returned to their farms and the co-designing phase started with the SIA advisory support. The importance of the advisor for the transition toward sustainable ICLS was highlighted by F9 "*If I had undergone only the FC, maybe I would not have put it into practice (…) because then, you depend on a lot of things; it is a series of questions.*" One strategy used to transition was to choose a test area to simulate the process on a small scale. According to F2, "*We started on small areas that I call 'laboratory,' with 20 hectares module, but today we have 80 hectares regenerating the soil.*" Furthermore, F5 declared that "*It emerged as a way to start this project, although on a small portion. If it did not work out, it would not have compromised the whole scheme. We would gradually start to advance this into other areas.*" Similarly, F7 developed "a demonstrative area" to show the working principle to their staff. *"We developed 12 hectares. We did it right, fertilized it with urea, and stocked it with cattle, 600–700 kilogram of liveweight per hectare. This was in the first year, now we are in the third year, and already working on 400 hectares. Now, it is no longer a problem to have cattle in the crop area."* Addressing the learning period he required during the transition, F10 stated that, *"The first year was a disaster, I made a lot of mistakes in grazing management (…) I am glad I did it in a small area. Our ICLS unit was 7 hectares. After that, I said to him (the advisor), 'Look, I want you advising me for the entire area.' Then, livestock commenced (to be raised) in the summer; I started with fertilization and management, of course!".* The Table 3 summarizes the farmers whose advisors proposed initial test areas that ranged from 7-82 ha and corresponding from less than 1% of the total area to 7.5%. The objectives were mainly related to pasture management and ICLS (Table 3).

Table 6. Summary of farmers interviewed who reported implemented test areas in their farms. The test areas (a small percentage of the total area) were one of initial steps to allow transitions toward sustainable farm practices with SIA advisors. "Rotatinuous" stocking means a new concept of pasture management based on animal behavior.

Farmer	Test area	% Total area	Objectives	How did they achieve it
F1	a) 62 hectares b) 47 hectares c) 82 hectares	a) 5.6 b) 4.3 c) 7.5	a) "Rotatinuous" stocking b) System-level fertilization c) System-level fertilization	a) Implementation of the sward height targets to maximize animal intake b) Assay of 100% of the nitrogen supply in pasture (rotation maize in summer x pasture in winter) c) Assay of 100% of nitrogen supply in maize versus 100% in pasture*
F2	20 hectares	0.4	"Rotatinuous" stocking + Start integrated crop-livestock system	Implementation of the sward height targets to maximize animal intake + Project a long-term ICLS implementation over whole farm
F5	60 hectares	2.2	Start integrated crop-livestock system	Inserting animal production in rice-monocrop area
F7	12 hectares	0.3	Start integrated crop-livestock system	Inserting animal production in rice-monocrop area
F10	7 hectares	1.4	"Rotatinuous" stocking	Implementation of the sward height control based on maximize animal intake
F12	6.5 hectares	1.0	No phytosanitary control in soybean	Testing a no phytosanitary control in soybean area with analysis of weed spread*

*With researchers´ help in the conducting and evaluation

3.4 On-farm challenges noticed throughout the process

An ICLS adoption challenge experienced on-farm was mind-set of people involved in the farming production. So, one important point is to raise awareness about ICLS importance to farming sustainability. According to F1, "*This is fundamental (in reference to people awareness) because the communication between crop farmers and their livestock counterparts is poor (…)*. Notably, F3 experienced this constraint with working teams: "*There were several meetings to avoid having two teams (one team for livestock and one team for crop); it is just one team, it is the farm (team who) is essential to increase profitability. Thus, both sectors have to be well aligned, one depends on the other, in fact!*"

On-farm partnerships between livestock and crop farmers are common in southern Brazil and are handled in various resource use contexts (e.g., the landowner owns and raises the cattle, but not the crops and machinery). Some relevant examples were pointed out in the interviews. For instance, F11 commented *"There was rice, and we made the arrangement to introduce cattle in the crop areas. However, the partner did not want to remain committed to the new farming model. He thought that it was not feasible, that it would turn the rice operation impracticable (...) Now we need to reorganize it. I think there is a great possibility because the new partner understands the need for soil conservation and crop rotation with cattle; he is already doing that."*

Some common points in the interviews are noteworthy, such as the importance of all decision-makers being on the "same page." A clear example was F1, who participated in the first edition and was unable to put many actions into practice because his father did not understand the logic of an ICLS; thus, his father was enrolled for the third edition. Similarly, F7 paid the technician of their rice-partnership to participate in the following edition to make him understand the ICLS concept.

3.5 On-farm results achieved

F7 had a win-win situation: "*We have a percentage (of rice production). And that was where I thought that the rotation system fitted well. (…) we believe that our share will be greater in the future due to his greater harvests (from ICLS benefits). So, it is mutually beneficial (…) Moreover, the results are already evident, even faster than I thought. The challenge, however, was the grazing on the top of the levee (soil structure constructed for irrigated rice), which we were unaware of (prior to SIA advisory)."*

For F3, whose background was non-agricultural, the importance of learning about ICLS was fundamental. According to him, "*I was able to explain my actions to my employees; why I was fertilizing the soil, as well as why I was rotating and practicing ICLS in those areas.*"

Besides technical and economic aspects, the ICLS also had an impact on family wellbeing; as F10 mentioned that, *"I think that initially it brought more financial stability to the farm (…) and also sleeping quality; I think it got more stability."*

3.6 Specialized advice influenced the ICLS implementation

All the interviewed farmers noticed the importance of the advisory to implementing the FC initiative. Nine farmers had already started the process with SIA advisories before the FC, while three commenced just after the workshop (Table 2).

Participant F2 highlighted that the advisory input offered "*A lot of safety, knowledge, and information; we developed the project together.*" Concerning land-use planning, F5 stated that, "*The crop team and the livestock team worked separately, then (after advisory) we were integrated.*" About "Rotatinuous" stocking, F9 pointed out, "*That basic principle, management of pasture height (…) That has changed our reality significantly.*"

Furthermore, F10 revealed that, "*The FC and the advice received gave me a direction (…) Before, I felt like an agronomist planting soybean as everyone does, somewhat dependent on inputs. The ICLS enlightened me about that. It opened a new world for me. The vision of the system, you perform an economic analysis, leads to sustainable activity.*" Additionally, new strategies were noticed as F9 explained; "*Today we follow these principles, having acquired experience from other cultures.*" Notably, F10 stated that, "*I remember that one of the first changes I noticed was that as early as the first or second meeting (with the SIA advisor) we started developing summer pastures that I did not know about. I was into soybean production, but now I have been introduced to pastures, thanks to the advisor's talent.*"

Complementary to on-farm technical advises, after the first edition, five participants were interested in following the coaching work in an individual format with the company's psychologist (the same one involved during the workshops). In the second edition, two people were also interested. Therefore, for each participant four monthly sessions were programed, each session lasting 1h, 30m. During the sessions, coaching tools, active listening, and mentoring techniques were used to favor emerging transitions and put in action other objectives placed in the action plan (step 4 of FC). This individual coaching works as a feedback of the progress and helps in unblocking challenges that appear during the implementation process. One example of a farmer who participated in these individual sessions was F6, who could organize his family routine as he explained: "*Since FC, every Monday, at 8:30 a.m., we have a family meeting; my daughter, my wife, and I (…) This is one of the things we brought in and implemented.*"

In addition, F1 and F5 demanded on-farm psychological advice to help managers and relatives change mind-set (e.g., managers who prefer to continue crop-livestock spatial separation as they do not agree with the transition toward integrated systems) and setting strategies to help communication (e.g., meeting mediations).

4 Discussion

4.1 FC experience as a key first step for transitions to emerge

The FC initiative represents a "take-off" transition phase toward diverse and sustainable farming, changing mindsets, and promoting new beliefs and values, which denote a key first step toward any emerging transition (Darnhofer, 2015). Concomitantly, FC is an efficient way to connect researchers, farmers, and other stakeholders who are involved in farming systems. Ingram et al. (2020) points out that co-innovation involves a complex interaction between contextual forces and requires facilitation processes; in this sense, FC provided concepts and guidelines to initiate a series of complex actions oriented to co-design diverse complex production systems (i.e., ICLS).

Our participatory methodology proposed followed the four principles Gibbon (2012) states: (i) systemic and group learning process (by the sequence of learning proposed toward systems thinking), (ii) acceptance of stakeholders' multiple perspectives (well represented in the co-design during the game and on-farm afterward), (iii) facilitation leading to transformation (mainly on-farm with advisors after the training session), and (iv) learning leading to sustained action (by focusing on farmers´ empowerment and dealing with barriers to emerging transitions). We organized our discussion part following these four principles to highlight the main originalities and limits to our work, as well as its out-scalability.

4.2 How does Farm Coaching favor systems thinking at the farm level?

4.2.1 Connecting researchers, advisors, and farmers

Participatory methods that rely on a close relationship between researchers and farmers can support the latter in exploring new management processes or in integrating innovative technologies into their farming systems (Barnaud et al., 2018; ComMod, 2005; Etienne, 2014; G. Martin et al., 2012; Le Gal et al., 2013). This is characteristic of the FC strategy that involves researchers and cutting-edge knowledge. Besides, FC provides co-learning opportunities through facilitated methods and allows actors to share pleasant moments.

FC´s main technical content is the ICLS, which encompasses soil conservation and management, spatial-temporal planning, grazing management, nutrient cycling, and personal development. Some concepts were recently proposed through research (e.g., system fertilization, Bernardon et al., 2020; and "Rotatinuous" stocking, Savian et al., 2018); thus, FC could be considered as a pioneer, diffusing cutting-edge knowledge, and bridging the gap between research and the field, thereby promoting knowledge exchange.

To design innovative agricultural production systems, Le Gal et al. (2011) concluded that only a few studies connected, in a single research framework, the three main components: biotechnical processes, farm management, and advisory services. They proposed a framework to improve research efficiency and ultimately support farmers' design processes, where the main potential innovative actors would be farmers as decision-makers, advisors as support providers, and researchers as producers of both technical and methodological knowledge. In our study, we connected these three components, while ensuring a rich dialogue and a good co-learning experience.

Duru et al. (2007) and Nelson et al. (2002) emphasized that tools and models needed to focus on the learning processes, as they are facilitators for discussion rather than decision support tools. For example, Kelemen et al. (2013) used a focus group method (i.e., small group conversations on a specific research topic aiming to get to know the group´s opinion) and found that this set up could help participants conceptualize complex topics, such as their perceptions of biodiversity. We used this approach to introduce a systemic view via FC gaming. Similarly, The Companion Modelling approach facilitates collective decision-making when faced with a complex situation by an evolving, iterative, and continuous process (ComMod, 2005).

4.2.2 Changing the farmer’s mindset toward a specialized to a systemic approach is the first step toward emerging transitions

The technical-personal blending in FC brings originality to sustainable ICLS transition research as it considers explicitly the farmer’s motivations. Our methodology follows Voinov et al.’s (2016) recommendations stating that *substantive transitions cannot occur without significant changes in human behavior and perceptions*. Therefore, we have largely emphasized the farmer’s mindset and considered the psychological aspect explicitly.
Brazilian agriculture is on a trend of specialization, highly dependent on off-farm inputs and increasing yield ceilings while decoupling crops and livestock (Garrett et al., 2020). This model is detrimental to the environment because of low diversity and nutrient pollution (Lemaire et al., 2014), besides increasing the financial risk (Ryschawy et al., 2012). However, specialization represents the main trend in agricultural management (Garrett et al., 2020). All stakeholders are so beguiled by this farming model that they cannot perceive its inherent damages or reflect on alternatives. In this way, the first step in FC was important in the deconstructing of the *modus operandi* represented by specialized farming.

The second step was to develop a new system thinking paradigm, which entailed capturing the “logic” of the farming system and focusing on the “bigger picture” (Darnhofer et al., 2012). The serious game session was an useful approach to practice the systems thinking concept in learning loops (Argyris and Schon, 1996). Asplund et al. (2019), in their study on how farmers perceived the impact of climate change, also stressed gaming as an important strategy that could function as a revelation to new ways of thinking.

4.2.3 Simplifying agricultural techniques though the serious game to favor the understanding of relevant integration practices

The FC game allowed participants to experience the consequences of chosen scenarios of land use scenarios based on space and time, followed by a debriefing with researchers and advisors. Furthermore, after that, the strong interaction with qualified advisors allowed adapting the scenarios explored over FC on the farm by iterative loops of deep re-design.

It is noteworthy that new technologies and practices precede socio-technical transitions in farming (Darnhofer, 2015). As Moraine et al. (2014) stressed, the ICLS design required methods to assess the systems using the iterative cycles that move between the participant's ideas, scientific knowledge, and stakeholders' visions. The serious game developed at FC fulfilled this role as a tool (model) to learn ICLS planning. As in the Maladaptation game, wherein the objective is for the players to make decisions regarding climate change adaptation (Asplund et al., 2019), FC players have positive judgments about the way the game can simplify a complex concept. However, the simplification of practices that we proposed in our game was sufficiently detailed for farmers to understand the system logic but inadequate to allow them to implement it.

The serious game proposed plays a didactic role in teaching the strategy of integrated systems strategy but does not cover each farm´s series of specific situations (sales of different animal categories, irrigation of most of crops and pastures, implantation of trees, other animal species, etc.). Because the game was developed partly with computer assistance, it limits access to illiterate people or people without digital skills. Also, the game deals with participants´ openness to others' perspectives and effective communication within a group (Bakhanova et al., 2020). Besides, the serious game in its current form, is restricted to the learning context and cannot be used for actual decision making without customization. On the other hand, it could be easily scaled out by updating the parameters to other regions of the world.

4.2.4 Coaching farmers to foster wellbeing and leading to transformation

Parallel to changing the farmer´s mindset about existing farming techniques, methods of personal organization (e.g., time planning and prioritization) and psychology techniques (e.g., developing communication, establishing of goals) were important to prepare the participants for more complex changes, which was stated as a major ICLS impediment (Asai et al., 2018; Ryschawy et al., 2013). The health of farmers and their workers is a source of growing attention, especially since there is societal pressure to practice farming in a less risky and in a sustainable way (Hostiou et al., 2020). This is particularly the case in ICLS since managing both crop and livestock working organizations is critical. The interviews suggest the workshop contributes to mental health since it bestows to the participants soft skills, such as time management and assertive communication.

In ICLS, aligning team thinking is essential to avoid the separation or even the generation of rivalry between those involved only in livestock or crop tasks. A farm's human resources range from just owner-operator to teams that bring the need for recruitment, management, and retention, as well as communication and leadership skills of those involved (Dockès, 2019). It was interesting to note in the FC that one participating farmer paid his manager to go to the next edition and another farmer paid the registration fee of his tenant's farm manager, both to ensure a synergy of thoughts and consequent decisions. In this sense, the participation of all decision makers (whether owners or managers) of the farm in workshops such as these helps in transitions. Another point is the involvement of the family; in one FC edition, four brothers chose to participate together to determine together as a family the new directions of their farm and to create new management routines. An emerging idea to be tested would be to carry out FC on-farm with everyone involved, especially in the case of farms with large teams.

There are some other coaching methods related to agriculture reported in the literature that bear similarities to our proposed approach. This is the case of the proposed "business coaching" to transform the health and safety of farmers in Australia (Blackman et al., 2015). In this conceptual approach, the use of the coaching methodology, as it considers adults' learning needs, would contribute to higher levels of motivation in addition to increasing the capacity to manage complex situations, which is the case with integrated systems. Another approach Bloksma and Struik (2007) proposed presents the metaphor of farm health to human health. The authors proposed redesigning elements of the farm to ensure the entire farm would be healthier. They presented a comparative table where, for example, they related human metabolism to the conversion of resources into products and waste on-farm and as an example, pointed out improving this aspect of the coupling farms for exchanges of feed and manure.

In our approach, we highlight the importance of carrying sustained actions, with the implementation of personal coaching goals and on-farm technical goals. Blackman et al. (2015), also proposed the same sequence of a group phase of creating objectives and action plans, followed by an iterative and individual "maintenance" phase for developing the actions and better performance.

4.2.5 Engaging emerging transitions in practice: The role of advisors

After the FC experience, comes the challenge to put the action plan into practice. At this stage, advisors play an important role as they scale out research proposals and support farmers (Le Gal et al., 2011). Thus, here there is a huge challenge when further integrated since the specialized nature of many advisory systems centered in a single crop or livestock species and not on a system scale (Garrett et al., 2020). The advisory supporting ICLS operations reported in this work is unusual and we were able to understand how farmers that had experienced FC and decided on an on-farm transition toward a new way of farming.

The advisors who conducted the on-farm SIA ICLS advisory noticed easier communication and greater speed in implementing processes related to ICLS with the farmers who participated in the FC. This shows how the FC functioned as a "trigger event," that is, a major change in the trajectory of the practices on the farm and in the structure of its businesses (Sutherland et al., 2012). We also emphasize the importance of immediate advising after trigger events to avoid stopping in the first challenges in practice.

The role of advisors after FC is to help in adapting the new knowledges mobilized and to encourage trying the first steps as testing areas. Also advisors play a coach role by empowering farmers with techniques, knowledge, and insights to help build solutions (Dockès et al., 2019). Dockès et al., (2019), highlight that roles will vary depending on the situational basis; a coach's role changes along with the classic role of expert, where the farmer's demand is for direct technical responses. In ICLS advising, we note another challenging role, which is that of mediation: be it between livestock and crop farmers, or between crop and livestock employees, as well as contracts of landowners and leaseholders. In summary, all these roles need to be present and configure the consultant's potential in dealing with transitions toward ICLS.

Another point to engage farmers is their relationship with the advisor. The relationship will be successful if the farmer trusts the consultant. There are 3 forms of trust: i) companion, which involves informal coexistence; ii) competence, based on the consultant's training and the advising company's perfection of competence; and iii) commitment, which comes from contractual arrangements (King et al., 2019). In this sense, building trust takes time, demands professional training, and is a formal and clear contractual relationship. Therefore, the success of the advising is built over time and can occur with a certain advisor of a company, but not with another one due to the farmer's perception of trust.

Prager et al. (2016) point out as great advantages of receiving advice from private organizations to personalization, of the direct interaction with each farmer, and the knowledge exchanges between the advisors. On the other hand, they point out that these organizations generally have poor connections with public research and education. In this sense, it is imperative to emphasize the importance of the partnership between the universities' research groups together with SIA for formatting and executing the FC. To replicate the proposed method, it is important that the arrangement and alignment of researchers, the field advisors, and the professionals with training in coaching together supply a robust and effective work.

4.3 Possible adoption barriers of Farm Coaching for transition toward sustainable ICLS

A team with advanced training (researchers and advisors mostly with a PhD) carried out the proposed methodology; this implies that reproducing of the methodology becomes restricted to the coaches' agenda. In addition, the workshop lasted 2-4 days and took place in one city at a time, which limited the participation of some interested people who were living too far away or were too busy on their farm. The first edition was longer (four days) and the time was condensed in the following editions because those who lived far away ended up having two more days of displacement (round trip). In addition, Brazil is a country with continental dimensions, thus even if the displacement is on the part of the team and coaches and not of the participants, it becomes expensive.

Another possible limitation to replicating this work is the on-farm advisory stage, since the availability and access to advisors with training and experience in ICLS is still scarce (Gil et al., 2016; Garret et al.,2020). Even more so, in the Brazilian context, adopting ICLS is a recent phenomenon (Gil et al., 2016), which the raises the demand for advisors to design the integrated systems. Furthermore, the common individual crop or livestock advising is not prepared to provide ICLS services (Garret et al., 2020).

In this work, we analyzed only the perspective of farmers with SIA advisory allowing transitions to emerge after the FC. The post-workshop trajectory of the other participants was not analyzed and could be interesting to create a parallel. The workshop is a sensitization phase. Thus, its application without a sequence of monitoring and individual customization may not be efficient in the transition to sustainable ICLS. The learning sequence proposed in the workshop also presupposes the participants' openness to undergo the deconstruction of the modus operandi, which may not be accepted by everyone. Some participants noted that there was no point in just having one person from each farm participating in the workshop, as everyone involved needed to be aware and willing to make the transition to sustainable ICLS.

5 Conclusions

The FC initiative was successful in setting up emerging transitions toward sustainable ICLS. The workshop allowed for participatory planning among farmers, stakeholders, advisors, and researchers. FC was considered as a pioneer, diffusing cutting-edge knowledge as the "Rotatinuous" stocking and system-level fertilization concepts. By considering the psychological dimension, the technical-personal blending, and how it deals with psychological barriers to ICLS adoption, the concept is positively oriented for disrupting the contemporary modus operandi of farmers' reasoning and judgment of the system components.

The connection between researchers and advisors was fundamental in constructing the workshop steps for conduction with farmers and stakeholders. Additionally, SIA advisors, empowered with concepts, tools, and adaptive strategies, were able to help farmers to start transitions to recoupling crops and livestock on-farm. Some strategies, such as farm designing, small field plots testing, and training of farmworkers, were presented as the first steps to allow such transitions to emerge. Looking ahead, we encourage using FC for sustainable transitions in other agricultural contexts, customizing it to cover additional farmers´ profiles, languages, and geographical regions. The next step will be to adapt FC to other contexts to scale it out, to reach more people, and to help them to engage in emerging transitions toward sustainable ICLS.

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CHAPTER III

A SERIOUS GAME TO ENABLE TRANSITIONS TOWARD INTEGRATED CROP-LIVESTOCK SYSTEM FARM DESIGNS: A CASE STUDY IN BRAZIL

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Abstract

In integrated crop-livestock systems (ICLS), crops, animals, and soil interact in space–time, generating synergistic properties. ICLS design is more complex than specialized systems design owing to their multiple interactions; hence, appropriate, and innovative methods and tools are required to facilitate the design process. We propose a serious game (named SIPA game – SIPA is the acronym of ICLS in Portuguese) as part of a thematic workshop (Farm Coaching) in which gaming fosters participants to try ICLS design strategies and farm-performance related consequences. The game was built to provide experiential learning, as the farmers assume the role of farm designers. Besides, researchers and advisors act as mediators of the final scenarios, contributing to reflections on both the concepts mobilized and the related technical challenges. We ran four workshops with 90 players in southern Brazil and interviewed 12 farmers to analyze their perceptions and connections with their realities on their farms. The game allowed players to co-design scenarios and understand the logic of ICLS decisions while promoting dialogue and stimulating reflections on ICLS farm design. The interviews showed that the SIPA game allowed farmers to connect what they had learned in Farm Coaching with their realities. It also served as a platform for exchanging knowledge and perspectives among farmers, researchers, and advisors. Newer versions and the application of the game for scaling-up to farmers are expected to continue as it seems a promising learning tool for inspiring transitions toward the adoption of ICLS. SIPA game is the first tool specific to ICLS farm design that exercises system thinking and budget planning in connection with temporal soil space use.

Keywords: participative approach; learning experience; crop rotation; land use; farm model; scenario conception.

1. Introduction

Integrated crop–livestock systems (ICLS) are recognized as a sustainable approach to intensify food production by contributing toward global challenges such as food production, land sparing, freshwater saving, greenhouse gas emission reduction, and the protection of ecosystem functions and services (Bonaudo et al., 2014; Garrett et al., 2020). Carvalho et al. (2010) highlighted that one of the premises of integrated systems is a precise and deliberate purpose of integration, a holistic view different from simple crop rotation or income diversification. Successful integration improves the synergistic relationships among components (i.e., the whole is greater than the sum of its parts) and results in enhanced social (including community), economic, and environmental sustainability, in addition to improving the livelihoods of farmers (FAO, 2010a).

To achieve these potential synergistic effects, it is necessary to consider ICLS farm design and how integration will be established, looking for sustainable transitions. ICLS designs are more complex than specialized systems owing to their multiple interactions; hence, appropriate methods and tools are required to facilitate the characterization and assessment of designed systems (Moraine et al., 2014b). Additionally, there is a lack of methodologies that enable design learning and access to land-use decision-making (Speelman et al., 2014). In this regard, games with an interactive format can help to improve co-designing (Voinov et al., 2016), helping farmers take time from their daily routine for a moment of reflection and planning. In this sense, role-playing games, in which players have a hypothetical role, might have better long-term outcomes than just watching a simulation, as this kind of games provides a safe environment in which players be the protagonists, allowing exploration with a balance between embeddedness and distance from the situation (Berthet et al., 2016).

Duru et al. (2015) identified the need to develop learning-oriented tools designed to create a language shared among researchers, extension workers, farmers, and other stakeholders. The authors emphasize the importance of boundary objects such as board games, cards, cognitive or geographic maps, and computational models to assist in simulations of the spatiotemporal distributions of crops, livestock, and semi-natural habitats.

Several serious games have previously been proposed as ICLS learning tools (Table 1). Despite the diverse functionality of each of these existing games, there is no single game that combines farm design, including spatiotemporal land-use distributions, with cash flow parameters and forage balance in an integrated system. To date, a model that demonstrates the importance of considering both crops and livestock and highlights the effects of decisions related to privileging investments on the entire system has not been reported.

Table 1. Examples of serious games that address integrated crop–livestock systems. The components of the integrated system that are directly addressed in each game and the scale of use are presented as game objectives.

Serious game	Source	ICLS components	Scale of use	Goal
SYLVOPAST	Etienne, 2003	Forest, grass, and sheep	Between farmer and forester players	Supports the negotiation process during the establishment of a silvopastoral management plan
SEGAE	Jouan et al., 2020	Soil, dairy cattle, forest, and crops	Farm level online simulation	Assesses impacts of farming practices on indicators related to sustainability
DYNAMIX	Ryschawy et al., 2018	Feed and manure	Landscape level (between a group of farmers in a set region)	Designs technical and organizational scenarios for establishing trade relationships (buying/selling) among farmers
FORAGE RUMMY	Martin et al., 2011	Beef and dairy cattle, and crops	Farm level real data simulation	Engages farmers and extension services to be the main players in livestock system design and evaluation
Role-playing game	Salvini et al., 2016	Forest, coffee, and beef and dairy cattle	Farm level simulated scenarios	Explores the consequences of land-use decisions on assets

Considering the importance of learning experience and the lack of a serious game specific to ICLS farm design that exercises system thinking and budget planning in connection with temporal soil space use (Fig. 1), our study addresses the following question: can a serious game devoted to the goal above ensure a satisfactory ICLS design learning process? Accordingly, the objectives of this study are to (i) characterize the development of the game as a method of fostering holistic ICLS design, (ii) compile game outputs, and (iii) analyze farmer interviews, relating their impressions and learning via the game.

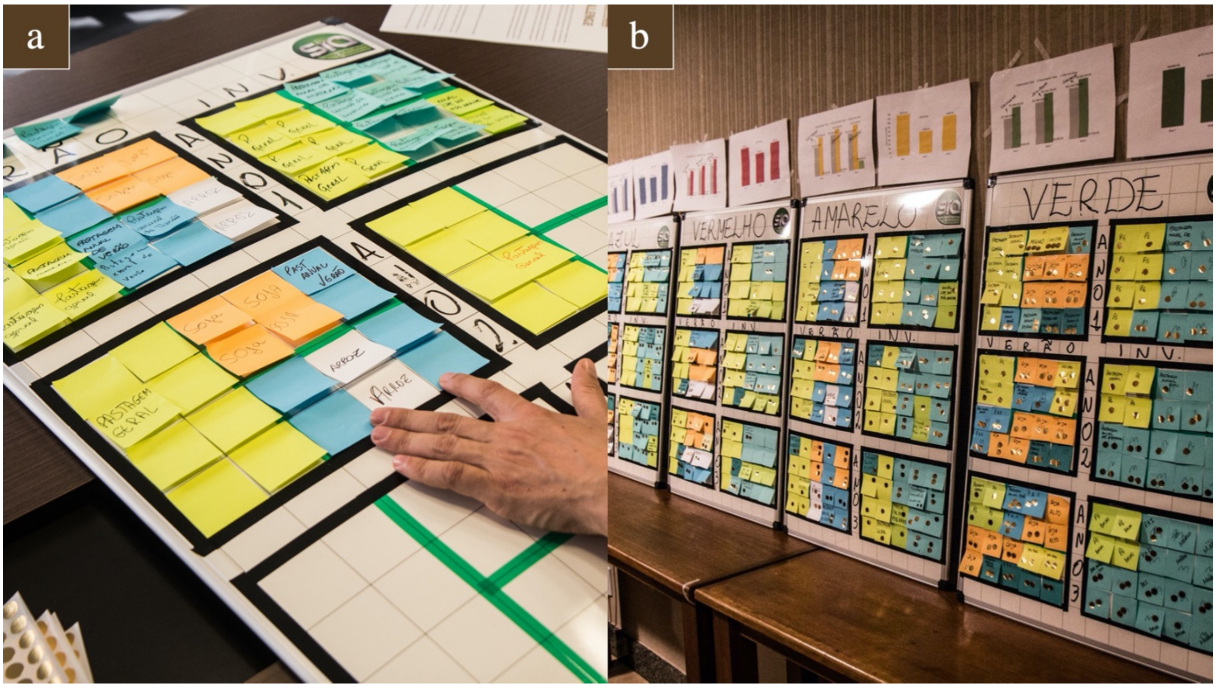

Fig. 1 a Land-use planning being represented in a board. b Scenarios of ICLS

2. **Material and Methods**

2.1. Overview of Farm Coaching

ICLS has been adopted in Brazil, particularly in recent years (Garrett et al., 2020). However, it is still challenging because designing such systems involves dealing with barriers beyond the technical dimensions of ICLS. In this context, the SIA (Serviço de Inteligência em Agronegócios), an innovative company in Brazilian agribusiness consulting, together with ICLS researchers from public universities belonging to Aliança SIPA (ICLS Alliance), were pioneers in developing a workshop for stakeholders involved in ICLS design. The workshop was named Farm Coaching, an innovative system blending technical and personal approaches to deal with psychological barriers to ICLS adoption and design. The workshop consists of four steps, and in the third step, a serious game session is held to provide a practical dynamic to what was presented in the previous steps (Figure 2). Therefore, a game was designed specifically for this workshop and named the SIPA game.

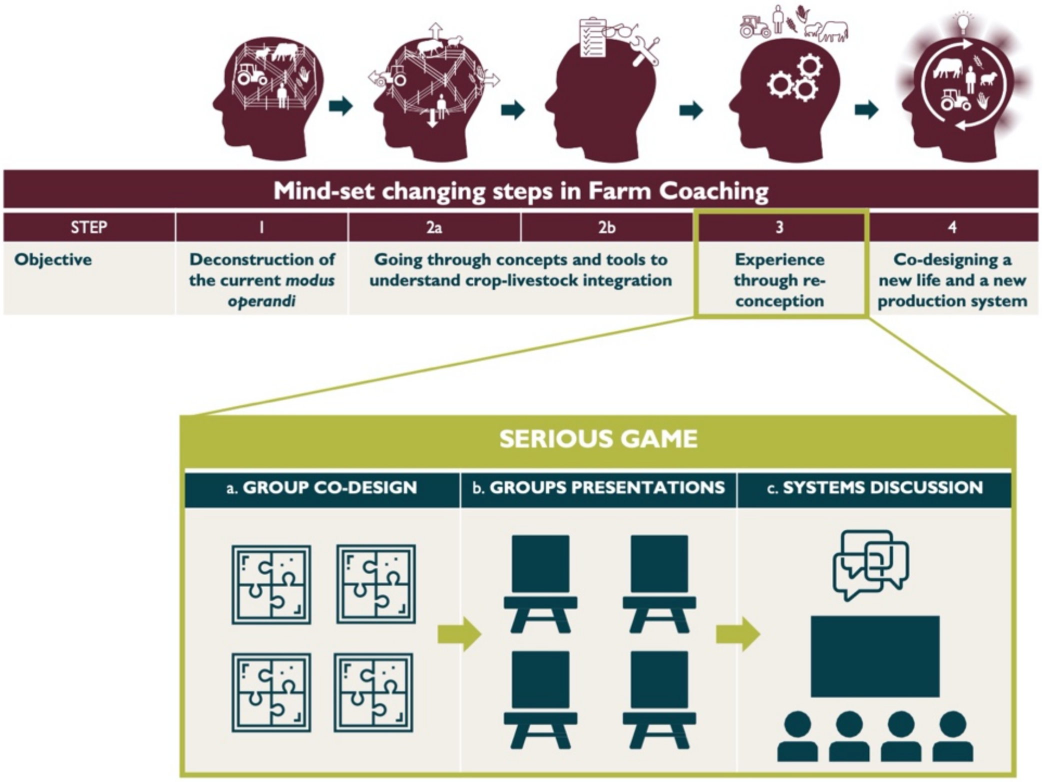

Figure 2. Four mindset-changing steps covered in the Farm Coaching workshop. Adapted from Moojen et al. (in press). The game session is included in the third step.

Four Farm Coaching workshops were conducted between 2017 and 2019. Additional information on the initiative can be accessed in the report by Moojen et al. (in press). Three workshop editions were held in Porto Alegre, the capital of Rio Grande do Sul, Brazil, and one in Cascavel, a city located in western Paraná, Brazil. A total of 61 farmers and 29 other stakeholders (three students, six project managers, 15 advisors, three farm managers, and two sales representatives) attended the workshops (Table 1). Each edition of the workshop included approximately 22 participants, divided into four groups comprising five to six participants. The resulting 16 groups were named alphabetically (Table 1). All groups managed to complete the triennial planning assembly within the time limit of approximately 3 h.

2.2 Development of the SIPA game

The SIPA game was based on a hypothetical farm located in southern Brazil. The initial scenario represents a typical farm profile, where beef cattle and crops are present but not integrated, and most of the annual budget is allocated for crops. Therefore, participants are invited to assume the role of advisors and co-design a three-year land-use plan. The players have three resources: (i) game rules, (ii) a model, and (iii) a board game.

The cash crops chosen for the game sessions correspond to those mainly used in southern Brazil. Soybeans (28%), corn (9%), wheat (4%), rice (3%), and beans (1%) were the main crops harvested in the 2018/2019 harvest (CONAB, 2020). As 90% of the rice area is located in the Rio Grande do Sul State and 77% of the bean area is located in Paraná State, both were chosen as local crops (Table 2). Additionally, the geographic relief division was customized to the region in which the workshop was held (Table 2). In the Porto Alegre editions, lowlands represent the traditional land use of paddy fields with intensive rice monocropping based on intensive soil tillage and fallow periods between rice cropping (Martins et al., 2017). In Paraná, the limiting factor chosen was sloping land, which makes mechanization difficult (Table 2).

Table 2. Game versions applied in each Farm Coaching edition. Three versions were developed and customized according to location, local crop, and geographic relief division. Each edition had four groups; they are named alphabetically, as indicated at the bottom of the Table. Porto Alegre is the capital of Rio Grande do Sul State, and Cascavel is located in Paraná State (both states are in the southern region of Brazil).

	Farm Coaching edition			
	1st	**2nd**	**3rd**	**4th**
Year	2017	2018	2019	2019
Location	Porto Alegre	Porto Alegre	Cascavel	Porto Alegre
Participants	22	20	24	24
Farmers	17	12	19	13
Game version	1	2	3	3.1
Local Crop	Rice	Rice	Beans	Rice
Geographic Relief	uplands x lowlands	uplands x lowlands	arable x sloping lands	uplands x lowlands
Groups	A B C D	E F G H	I J K L	M N O P

2.2.1 Boundary objects in the game

Two boundary objects were included in the SIPA game: (i) a model and (ii) a game board.

i) Model mechanism that integrates land use and investment level decisions

We created a model in Microsoft Excel® to integrate land use and the level of direct costs (budget allocation and livestock *versus* forage budget). Therefore, when players make land use and investment choices, they experience four different responses: they either have cash or not and they either have stocking capacity or not (Figure 3). In each situation, they have four or five strategies to choose from or combine. For example, if a group chooses to increase the area and investment in a perennial pasture, they will likely have an excess of stocking capacity cascading the need to buy more animals. If they choose this strategy not having enough money, they will need to choose one of the following strategies: decrease pasture investment, decrease pasture area, or choose pastures with lower stocking capacity.

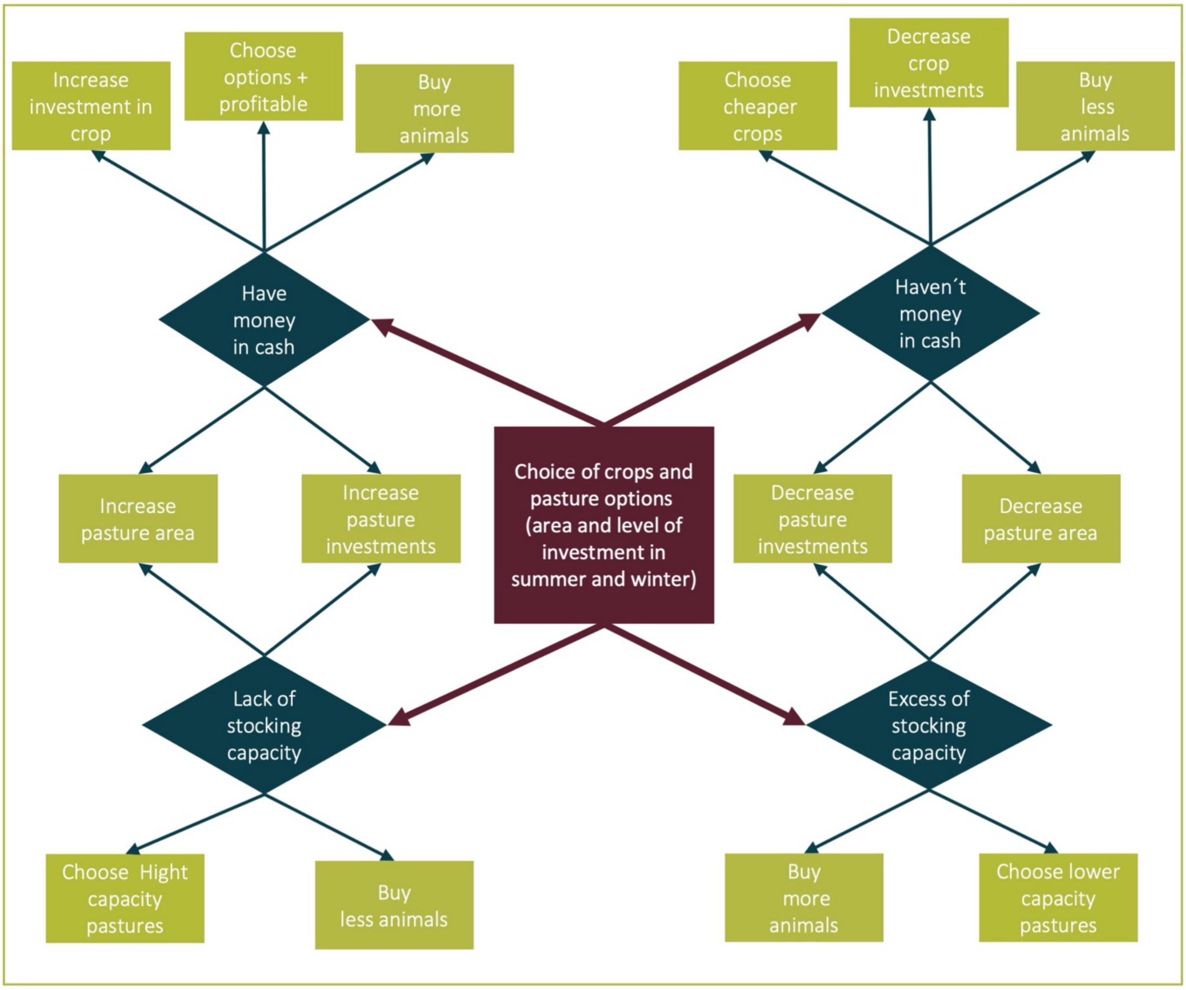

Figure 3. Logigram of the model used in the game. The central square indicates the main action of the players; this results in four responses (diamonds), from which they can choose four or five isolated strategies (rectangles) or a combination of them.

The advisors provide the model parameters—direct costs, income, and the stocking capacity of pastures—based on their current experience in the region (Table 3). The proportions between the level of investment and the expected results are maintained. The values were rounded to facilitate discussion.

Table 3. Parameters by crop/pasture option and level direct costs. Exchange rate used: 4 R$ = 1 $; Stocking capacity occurs only in pasture options. AU = animal unit (450 kg liveweight). PTP: Perennial tropical pasture; ATP: Annual tropical pasture; tPAR: temperate pasture after rice; and AtP: Annual temperate pasture.

	Level of investment	Direct costs ($/ha) Low	Medium	High	Income ($/ha) Low	Medium	High	Stocking Capacity (AU/ha) Low	Medium	High
Summer options	Soybeans	375	500	750	469	650	975	0	0	0
	Corn	250	375	500	325	500	675	0	0	0
	Beans	350	625	950	500	825	1,275	0	0	0
	PTP	25	150	250	50	300	700	1.2	3.5	5
	ATP	100	200	300	150	394	650	2	3.5	5
	Rice	1,000	1,250	1,500	1,100	1,437	1,775	0	0	0
Winter options	tPAR	112	187	262	137	287	462	0.85	1.8	2.5
	AtP	75	150	225	131	275	450	0.85	1.8	2.5
	Native pasture	0	12.5	25	25	62	100	0.5	1	1.5
	Wheat	250	1,500	500	300	469	650	0	0	0
	Cover crop	25	50	75	0	0	0	0	0	0

ii) Material for representing land use and didact analysis

A game board was designed to represent land use (Figure 4). It could be filled freely by the participants, as they were considered the designers. The groups were supported by researchers and SIA advisors that comprised a “support team” responsible for helping to solve questions during the game. The primary function was to present the results of each group in space (crop rotations and between-relief divisions) and time (two periods of the year and over three years). Thus, it allowed a visual comparison of the different strategies adopted between groups. Board improvements are presented in Section 3.2. Additionally, cards printed with the parameters used in the model were developed, but only tested in version 4.0 (see Section 3.2).

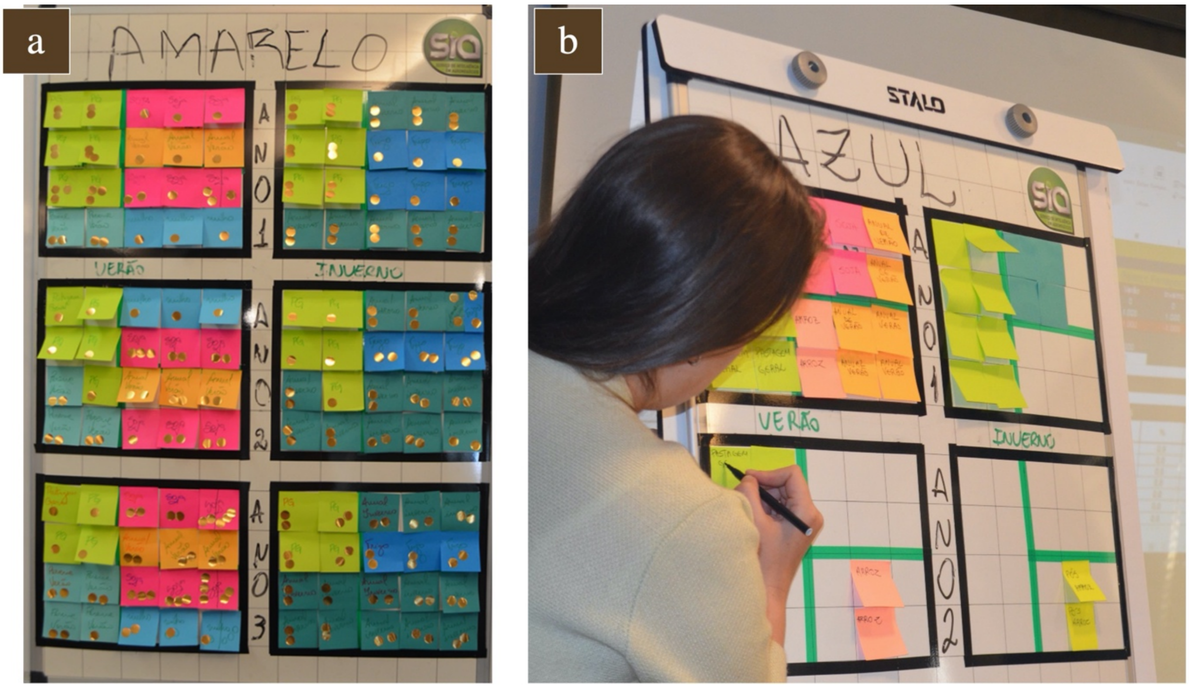

Figure 4. Pictures from the game session of the 4th edition of Farm Coaching. **A** Boardgame of one group. On the board, a 1,000-ha farm map is represented six times, showing the land use in summer/autumn and winter/spring, for 3 years of rotations. Each sticky note represents 50 ha, and their color represents the type of land use (soybeans are displayed in pink; native pasture in light green; annual tropical pasture in orange; maize in blue; perennial tropical pasture in light blue; wheat in dark blue; and annual temperate pasture in dark green). The round gold stickers on each post-it represent the level of investment (one sticker = low level, two stickers = medium, and three stickers = high). **B** A participant filling the board; the green lines inside each farm map indicate the relief divisions (lowlands and highlands) and native pastures.

2.3 Game session

Each game session begins with an explanation of the game (approximately 30 min). Then, the participants are divided into small groups to simultaneously co-design ICLS. To create the different groups, individuals are chosen to ensure similar combinations of occupations (all groups contained farmers and other stakeholders), ages, sex, and relatives (e.g., when siblings participated), to enhance debate during the co-design process. All groups received the abovementioned boundary objects and were allowed 3–4 h to play. In the game session, advisors facilitated several group interactions but avoided direct interference in their decisions. Finally, advisors and researchers carried out a debriefing step that facilitated an overview of the outputs and implications of the choices made in the game (approximately 1 h).

2.3.1 Game rules

The rules were conceived based on the knowledge of advisors and researchers related to actual farm cases in southern Brazil. All rules were tested in the model prior to the game sessions to ensure feasibility. They were presented to the participants as follows:

A. "The total area of 1,000 ha must be planned for 3 years with agriculture or livestock in both summer and winter seasons."

Rule A was created to encourage the maintenance of continuous food production in all potential areas and inspire players to consider crop rotations in their space–time planning.

B. "To optimize the available machinery, the minimum area of the summer crops should be 300 ha each year."

This rule was aimed at stimulating players to include agriculture instead of only livestock, taking advantage of the farm's infrastructure for an ICLS.

C. "The carrying capacity of the system should support a herd equivalent of at least 1,000 animal units (450 kg liveweight). *in both summer and winter."*

D. "The balance of the carrying capacity should be prioritized, avoiding both shortage (overgrazing) and excess (waste of resources) of forage in both seasons. The tolerance for miscalculation was defined as the equivalent to 50 animal units."

Rules C and D define the forage budgets for cattle, challenging players to distribute resources throughout the year.

E. "The hypothetical farmer desires to reinvest his profit from year 1 and year 2 into the farm and would like to spend part of the annual budget to purchase cattle and increase the herd as an investment."

This last rule is related to the wishes of the "hypothetical farmer" in the game, who was equivalent for all groups. The first-year budget is restricted to players' choices; however, owing to the reinvestment rule, players need to consider different budget scenarios over the 3 years. Additionally, the decision to increase the herd includes investing money not only in purchasing but also in having enough onf-farm pasture to feed the herd, which makes the game more challenging.

2.4 Evolution of the SIPA game between editions of Farm Coaching

The game (including the rules, model, and boards) was previously built and tested within the "support team." However, according to the participants' feedback, several improvements were incorporated into each edition. Three different versions were tested during the workshops. The fourth version was still not used by farmers, only by students at faculty. The evolution of the four versions is detailed below:

Version 1.0: In the first version of the game, the board was too small, which impaired presentation (Figure 5). Additionally, the model did not account for the cost of purchasing animals, which led to an unrealistic increase in herds, alongside unfavorable stock fluctuations over several years.

Version 2.0: In the second version of the game, in addition to a larger board, all three years and the two periods were clearly defined, alongside the relief within the area. The divisions (50 ha) had dimensions of 5 cm × 5 cm, and colored adhesive papers were used, improving the presentation of the board. The model was improved with the automatic generation of graphics. Based on previous participants' questions, the rules for Version 2.0 were more precise than those for the previous version. As the cost of purchasing livestock was considered, the financial results were reduced. Hence, it was necessary to separate the purchase of livestock as an investment and not just as a cost.

Version 3.0: In the third version of the game, it was necessary to adapt to the production context of the region (Paraná State). The relief was divided into "arable land" and "sloping land." Additionally, the option of rice crop was changed to beans crop because of its cultivation in the region. The distribution of colors by culture was also standardized to facilitate visual comparison between groups (e.g., soybeans were presented in pink).

Version 3.1: This version is the same as version 3.0, however, the relief divisions and cash crops were the same as those in versions 1 and 2, because the workshop was conducted in Rio Grande do Sul State.

Version 4.0: The fourth version was tested with students from the Universidade Federal do Rio Grande do Sul in Porto Alegre-Brazil and students from *École Nationale Supérieure Agronomique de Toulouse* in Toulouse, France. This version included cards printed using the parameters of the model. These cards facilitated the identification of the role of each culture in the game, its profitability, and its adaptation to seasonal conditions.

Figure 5. Evolution of the SIPA game board from left to right. Each picture was captured from the final presentations at each Farm Coaching edition.

2.2.1. Analysis of game outputs and farmer surveys

The outputs of the games, both from the model and the boards, were compiled, and the results are discussed in the next session. The results of each edition of Farm Coaching are presented; although comparisons between groups in each Farm Coaching edition are possible, comparisons between editions are not, owing to the differences in the models, tables, and regional adaptations. After each Farm Coaching workshop, 12 farmers (presented as F1–F12) were selected for individual online interviews to examine their perceptions of the game and how they connected it with real-world conditions on their farms. The interviewees were chosen from farmers who participated in one of the Farm Coaching editions, who had SIA monitoring on their farms, and who utilized integrated systems (rather than just cattle or crops). The interviews, all conducted by the same interviewer, were semi-structured, lasted about 1 h each, and were carried out between February and May 2020. After the interviews, they were transcribed and subjects common to several farmers were clustered. Some excerpts are presented in the results section to illustrate the impressions of these farmers.

3. Results and Discussion

3.1 Outputs from SIPA game sessions in Farm Coaching workshops

When compiling crop usage in the game (Table 4), participants used 60–100% of the options available. Several crops appeared with 100% frequency (soybean, perennial tropical pasture, and annual temperate pasture), and the lowest use (25%) was for cover crops; their use was discouraged as they were the only non-revenue generating option, without any food production or support capacity.

In the editions held in Porto Alegre, the options of "rice" and "pasture after rice" were added to the game, and only three of the 12 groups chose not to use this crop. F11 had rice experience on his farm and stated, "*I tried to explain to the people how rice was planted in a soil with water and about rice plots […] Because the soybean, corn, wheat crops are logical, one ends cultivation after another*," (referring to the fact that the production of rice irrigated with levees involves water distribution logistics, advance preparation of levees, and a significant amount of machinery). Additionally, F10 demonstrated his point of view regarding rice and compared it to his region *"Wear of machinery is awful. Area rental prices are awful. The input price is very [dependent] on the fertilizer input […] If it gets cold in January you lose the crop, if it stops raining and there is no water, you lose the crop. It is similar to wheat in my region, it is a high investment for a low return."*

Wheat was an option in all FC editions, but players in the first two editions did not choose it, and in total, only 44% of the groups utilized it. Despite its positive results in the game, farmers related it to bad personal experiences. Considering the conditions at his farm, F10 stated *"Wheat today is like that: the cost of a hectare of wheat well done is more than a hectare of soybeans for you to plant. And the risk is very high because lack of too much cold loses production, lack of heat in winter loses production, if it rains too much you lose production, if it rains less you lose production. There is a bacteriosis problem […] fungal diseases that are difficult to control. And if you have an excellent, excellent crop, it rains 3–4 days at harvest, the crop loses 30%, the HW (hectoliter weight - measure of wheat quality) drops, and the value has already dropped."*

Table 4. Crops and pastures chosen by groups in game sessions. White represents the absence of the crop, whereas black represents its presence, over the three years of rotation. *crop was not available

because of the regional context. PTP: Perennial tropical pasture; ATP: Annual tropical pasture; tPAR: Temperate pasture after rice; and AtP: Annual temperate pasture.

Farm Coaching edition		**1st**				**2nd**				**4th**				**3rd**				
	Group / crops	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**M**	**N**	**O**	**P**	**I**	**J**	**K**	**L**	**Freq.**
Summer options	**Soybean**	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	**100%**
	Corn				■		■	■		■	■	■	■	■	■	■	■	**69%**
	Bean	*	*	*	*	*	*	*	*	*	*	*	*	■		■	■	**75%**
	PTP	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	**94%**
	ATP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	**100%**
	Rice	■	■	■	■	■		■	■	■		■	*	*	*	*	*	**75%**
Winter options	**tPAR**		■			■		■	■	■		■	*	*	*	*	*	**50%**
	AtP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	**100%**
	Native pasture	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	**94%**
	Wheat									■	■	■	■	■	■		■	**44%**
	Cover crop											■	■			■	■	**25%**
	Freq.	**60%**	**70%**	**60%**	**70%**	**70%**	**60%**	**80%**	**70%**	**90%**	**70%**	**100%**	**80%**	**78%**	**78%**	**78%**	**100%**	

Increases in stock of cattle (through the purchase of animals) were explored by all groups, according to “rule E” of the game (Table 5). In the first edition, the purchase of animals was not considered an expense in the system, leading to a significant increase in the herd. In the second, third, and fourth editions, 308 animals, on average, were purchased over the 3 years of simulation (representing an increase of 30.8% compared to the initial stock), varying between 180 and 529 among the groups (Table 5).

Table 5. Group results for each edition of Farm Coaching. Exchange rate used: 4 R$ = 1 $. * In the first edition, the purchase of animals was not subtracted from the cash register. **Different local crop and geographic relief.

Farm Coaching edition	Group	Total Purchased Animals	$/ha gross margin over 3 years	Average	Standard Deviation
1st edition*	A	700	$ 634,44	$ 654,13	$ 149,04
	B	1488	$ 867,80		
	C	825	$ 527,27		
	D	878	$ 587,01		
2nd edition	E	270	$ 413,50	$ 450,31	$ 58,08
	F	466	$ 528,63		
	G	180	$ 399,81		
	H	200	$ 459,31		
3rd edition**	I	205	$ 609,81	$ 647,15	$ 79,87
	J	250	$ 744,81		
	K	529	$ 673,50		
	L	459	$ 560,47		
4th edition	M	230	$ 500,50	$ 531,86	$ 61,66
	N	424	$ 624,31		
	O	300	$ 503,38		
	P	188	$ 499,25		

All values were set in Brazilian national currency (R$), following domestic market prices for crops and livestock, and subsequently converted using the current exchange rates to US$. The gross margin (gross revenue – gross costs) increased over the 3-year simulation. This was expected because, following the rules, the margin was re-invested in years 2 and 3, which allowed for greater investments in existing crops and the adoption or augmentation of more expensive crops. The sum of the gross margin per ha over the three years of simulation was $ 654 ± 149, $ 450 ± 58, $ 647 ± 80, and $ 531 ± 62 (average ± standard deviation) for the first, second, third, and fourth editions, respectively. Apart from edition 1, which did not count the purchase of animals yet, the variation (standard deviation) between groups in the other editions was low, but the scenarios included different rotations, diversification of the culture options used, and different investment levels. Because of the similar economic results between groups, the debate at the presentation stage was focused on the implications of the choices made in terms of risk, operationality, farmer preferences, and long-term strategies.

3.1.1 Serious games in the Farm Coaching context

In each game session, it was interesting to note that the different scenarios proposed by the groups reached similar economic results, although they followed different farm design strategies. This demonstrates that no simple, optimal solution exists, and that contrasting spatial configurations can be comparable (Etienne, 2003). In this sense, the fact that the game model included multiple interconnected possibilities (see Figure 2. Logigram) allowed players to experience not only single-loop learning when exchanging strategic actions (equivalent to investment level and animal acquisition in the game), but also double-loop learning when changing the governing variables (equivalent to choosing crops and pastures, as well as their proportions in the area) (Argyris and Schon, 1996). Therefore, it is important to note that there is no single "recipe" to implement an ICLS and a co-designing process is required (Berthet et al., 2016; Lacombe et al., 2018a; Martin et al., 2013).

The Farm Coaching workshop influenced player decisions in the game, as they attempted to apply the information discussed in the workshop. Several players questioned whether the model accounted for reducing the use and cost of herbicides via appropriate grazing management and fertilization strategies. A long-term experiment demonstrated that higher sward heights in winter-grazed cover crops reduced the number of weed species, the density of emerging weed seedlings, and the weed seed bank size, compared with those in non-grazed cover crops (Schuster et al., 2016). Another experiment demonstrated that, in ICLS fertilization strategies, nutrient fluxes should be considered at the appropriate spatial and temporal scales to enhance land use by increasing energy production per unit of nutrient applied (Farias et al., 2020). Both experiments were presented during the Farm Coaching workshop; therefore, it was debated by farmers during the game. The SIPA game may, in the future, explicitly include these themes, or new games could be proposed during Farm Coaching to address these themes, as they are recent concepts and require a learning process to be implemented.

3.2 The SIPA game allowed farmers to compare ICLS to specialized farming

The game provided a realistic but simple representation of the ICLS practiced in southern Brazil. One clear example of how farmers made connections with reality is their discussion regarding the use of rice and wheat, which involve operational challenges and risks in practice, while being presented as profitable options. This means that the game has context-relevant content. Ryschawy et al. (2014) were also successful in connecting their serious game with reality and present this as a crucial point in its relevance to users.

Another aspect of the game's connection with reality on farms is the management of the herd in relation to forage budgets. Some farmers raised concerns that in the game they had to retain the animals throughout the year, contrary to the common practice of buying calves to fatten on pastures during winter (between two soybean crops). This practice of fattening for a short period (i.e., approximately 4 months) is possible with appropriate pasture management (Wesp et al., 2016), but is only applicable for farmers who work purely with fattening, without cow–calf operations in which animals are rested during the year. In addition, livestock management is challenging on farms with a high percentage of summer crops. In such cases, pasture area in winter is significantly higher because it often corresponds to the entire area of summer crops; in contrast, during the summer, the animals overgraze smaller areas, creating an imbalance. This is well addressed in our game because it is necessary to balance both the supply and demand for pastures and ensure balance between seasons.

3.3 Farmer perceptions regarding group discussions

By interviewing the 12 farmers, several perspectives were uncovered. One concern was about the individuals within the groups, which were pre-defined based on a profile analysis to promote participant diversity. F11 remarked, *“The main issue, which I remember most, is the need for understanding between different profiles of people […] it was even more difficult than the game itself.”* Conflicts were attributed to cultural aspects, such as livestock or crop farm backgrounds. This was illustrated by F12, who stated *“The game has put us face to face with practice […] But to play a game like this, I also need to have an improved cultural understanding. I can't just focus on my local culture, I need to drink from other cultures, from other sources, from another understanding and even break with cultures. When I talk about cultures, it's really social culture.”* Additionally, with regard to his group, F8 stated that “*It was a little conflicting, because there were defenders of a certain product, of a certain crop. The defenders of only purchasing cattle, only the part of the livestock. So, you had to really show the balance in this game, in the simulations and try to contain that urge, if you to have a surplus of cash, “let's buy cattle, cattle, and cattle.” But wait! There is no point in buying, buying, if I'm not going to have food.*”

3.4 Serious games as a tool for ICLS farm design learning

Designing an integrated system involves considering both crop and livestock management requirements, including landscapes, biodiversity, and strategic decisions (Jouan et al., 2020), and attempting to strengthen synergistic relationships. The multiple components and interactions that characterize ICLS remain a methodological challenge (Stark et al., 2018). Ditzler et al. (2018) stressed that tools for the analysis of agricultural systems must be designed for targeted audiences; thus, it is necessary to account for the complexity of the tool and language, cultural, and institutional barriers. In this sense, our game proved to be well designed for the target audience, as we succeeded in simplifying the design of integrated systems, so that Farm Coaching participants, after a brief introduction (steps 1 and 2) were able to play and practice the ICLS concepts presented.

Interestingly, regarding the farmers' perceptions of peer participants, they indicated crop or livestock backgrounds as an important point of debate. Therefore, we noted the importance of a game mechanism that encouraged farmers to rethink their performance criteria. This implies a shift from looking at the performance of each component (either crops or livestock) to focusing on performance per unit land. This meant designing and evaluating the production of the whole system, rather than their usual crop-oriented planning. However, to achieve this change in mindset, several aspects of system thinking are required: i) understanding interconnections among various parts and the whole and ii) viewing a situation/problem from different perspectives (Church et al., 2020). Church et al. (2020) also highlights that all farmers may inherently be system thinkers, but great variation exists in the degree to which they make connections within and beyond their production systems. Therefore, our game could help promote the methods and habit of system thinking during decision-making on farms.

In this work, the focus was on the analysis of the farmers' impressions, but it would be important to further explore the contribution of the Farm Coaching methodology in the training of ICLS advisors. Beyond this, the game was designed not only for farmers, as Farm Coaching also attracted stakeholders. It is important to emphasize the need for integrated system training for this audience as well. Garrett el al. (2020) points out the specialized nature of advisory systems as a negative driver in promoting extension services for the implementation and management of integrated systems.

3.5 Critical analysis of the game and insights

The construction, use, and study of serious games in agriculture has increased significantly in the past two decades and has proved to be an innovative way to accelerate dialogue and learning (Hernandez-Aguilera et al., 2020). However, despite increasing availability, the designed tools are not always effectively adopted by farmers and advisors owing to factors such as bad performance, insufficient ease of use, and insufficient relevance to the user (Rose et al., 2016). We propose several improvements that can be incorporated into our serious game to address these constraints. First, pre-set system boundaries are provided to players as a hypothetical farm, i.e., using identical initial scenarios to start the game. This facilitates the final dynamics of the game where the scenarios are compared; however, it does not represent the actual scenarios of farmers who play the game. Therefore, as an improvement, and perhaps as an additional stage after the game session, a realistic model, based on the game but with an initial menu for registering actual areas and data, could be used. Consequently, farmers would be able to simulate scenarios to be implemented, like in Forage Rummy (Martin et al., 2011), where the context of the game is based on the data of each farmer.

Another improvement pertains to the need for skilled facilitators in the final discussion because the model has no constraints and serves only to simulate people's decisions. Thus, it is important to include indicators such as risk, workforce, complexity, and sustainable indicators to ensure that the interpretation of the choices made does not necessarily require the presence of many advisors and researchers. The SEGAE serious game is an example with automatic sustainability indicators, realized by compiling scores (Jouan et al., 2020). Another source that can be added to the game is the "IDEA" method (IDEAv4), which contains 53 indicators to analyze Farm Sustainability (Zahm et al., 2019). Their pedagogical tool was developed to be easily calculable and interpretable by a farmer, an advisor, or a student.

In this study, we focused on the production of grass-fed ruminants because grazing animals are important in the dynamics of nutrient cycling in the soil (Carvalho et al., 2010). Pastures are also a cheap forage source, and the production of pastures in Brazil can be planned throughout the year. However, some players proposed the use of grain for animal feed; hence, it would be necessary to adapt the model more robustly, considering animal requirements and feeding options. The game could detail livestock practices and, for example, allow variations in animal species (e.g., adding dairy cattle) and include herd division based on animal categories, as proposed by Martin et al. (2011). Finally, an easier proposition to improve discussion in the game would be to include variations in the prices of both cattle and crops, as reported by Ryschawy et al. (2014). This would demonstrate that more diversified systems tend to be less affected by market variation (de Oliveira et al., 2014).

3.6 Inspiring transitions toward adoption of sustainable ICLS

Hernandez-Aguilera et al. (2020) state that well designed games are capable of generating emotional experiences and may also inspire farmers to change their behavior. In this sense, the interviews revealed how striking the serious game was for farmers at the Farm Coaching workshops. Lacombe et al. (2018) concluded their review on designing agroecological farm systems by demonstrating the importance of creating "reflexive arenas" that support farmers' changes on their farms. In this regard, knowledge exchange networks, field trials, and synthetized information regarding ICLS are considered important drivers for recoupling crop and livestock systems (Garrett et al., 2020).

It is worth remembering that there are tools developed specifically for ICLS design. An example is the SCOR[3] tool developed by INRAE and AGROTRANSFERT in France, which allows users to analyze the spatial and temporal coherence of crop rotation with animal production. This tool, as well as our game, allows simulation of the budget impact of animal feed balance with soil use and rotations throughout the year. Tools like this are important for users who are already encouraged or are early adopters; however, these tools cannot change the participants' state of mind. Thus, for farmers who have not yet adopted integrated systems, games can be much more assertive tools in changing awareness because they are easy to use, explanatory, and have boundary objects that assist in the learning experience.

4. Conclusions

Our findings indicate the potential of the SIPA game, which allows players to understand the logic in ICLS decisions despite being a simplification of reality. In addition, the game served as a platform for exchanging knowledge and perspectives among farmers, researchers, and advisors. Finally, the game is a tool that helps in inspiring transitions toward the adoption of ICLS. Based on these positive experiences, the development of new versions and the application of the SIPA game is expected to continue with new groups, thereby engaging participants in a learning experience centered around system thinking and planning, and potentially encouraging action toward sustainable ICLS implementation. The game is easily scalable for other regions of Brazil and even other parts of the world, using regional adaptations for the parameters inserted in excel. The pedagogical strength of the game should be exploited with agricultural students and advisors to empower them in helping farmers co-design sustainable ICLS.

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Declarations

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Conflict of interest The authors declare that they have no conflict of interest.

Ethics declarations Not applicable

Consent to participate The participants to the study were informed about the conditions and purpose of the research and gave informed oral consent to participate to the research. The data was anonymized after the end of the interviews.

Consent to publication The authors affirm that farmers participating in the survey provided informed consent for publication of anonymized data.

Data availability All data generated or analyzed during this study are included in this published article

Code availability Not applicable

Author's contribution Conceptualization, P.C.F.C., J.R., D.T.S. and F.G.M.; Methodology, D.T.S., A.B.N., P.C.V., P.C.F.C. and F.G.M; Investigation, D.T.S., A.B.N., P.C.V., P.C.F.C. and F.G.M; Writing – Original Draft, F.G.M., P.C.F.C., and J.R.; Writing –Review & Editing, F.G.M., P.C.F.C., and J.R.; Funding Acquisition, P.C.F.C.; Resources, D.T.S., A.B.N., P.C.V.; Supervision, P.C.F.C., and J.R.

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CHAPTER IV

Farm advisors are key to encourage crop-livestock at farm level: Perceptions and experiences in Brazil and France

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Abstract

Purpose: Our objective was to answer how advisors are encouraging the transitions towards reconnection of crops and livestock at the farm level.

Methodology: We conducted semi-structured interviews with 20 advisors and project managers currently working with ICLS in the Brazilian context of ICLS adoption and the French context of ICLS decreasing. The content of the interviews was analyzed.

Findings: Results present an analysis of the advisors’ main activities including communicate and facilitate farmers´ groups, support ICLS co-design, gather ICLS knowledge and mobilize tools, and assist on-farm transitions. Besides barriers as communication and levers as advisors’ exchanges were summarized.

Practical Implications: the study reveals the importance of understanding and learning how the advisor can help farmers to manage the complexity of space-time coupling in ICLS. This must be further included in training and can be supported in practice by strong cooperation between advisors.

Theoretical Implications: the article complements the existing scientific literature on advising skills and system thinking on ICLS. It also highlights the role of advisors, specifying activities, tools, and insights in developing of ICLS practices.

Originality/Value: This study highlights the specificities of ICLS advising and opens avenues for research on ICLS transitions subject.

Keywords: extension studies, knowledge exchange, mixed farming systems, rural development, sustainable transitions, technology adoption

1. Introduction

Integrated Crop-Livestock Systems (ICLS) are planned systems that involve livestock and crop production with interactions in space and time. It can be conducted within a single farm or at a territorial level (de Moraes et al. 2014; FAO 2010; Moraine et al. 2014a). In developed countries, the economic tendencies limited their development in place of a specialized way of farming (Bonaudo et al. 2014). However, ICLS are recognized as a sustainable way for food production since the complementarities and interactions between crops and livestock allow potential emerging proprieties as resilience, productivity, efficiency and self-sufficiency (Rachael D. Garrett et al. 2020; Bonaudo et al. 2014). To benefit further from these emerging properties, it is necessary to plan to strengthen these ICLS and, if need be, to reconnect crop and livestock systems.

The recoupling of crop and livestock production takes part in a more global agroecological transition (Elzen et al. 2017; Duru, Therond, and Fares 2015). Coquil et al. (2018) consider that agroecological transitions change both the work and the way farmers, advisors, teachers, and researchers collaborate. These authors assume that agroecology implies considering farmers´ singularities and local particularities, and this also changes the knowledge to be mobilized from a generic approach to take singularity into account. Garrett et al. (2020) highlighted the specialized nature of many research and advisory systems centered around individual crop or livestock commodities fails to provide adequate extension services to train farmers for ICLS management.

Looking into the dynamic of adoption/abandonment of ICLS over the world, Brazil and France are two countries that present contrasting dynamics. On the one hand, in Brazil, there has been a recent increase from 1.87 to 11.47 million hectares in 10 years (2005-2015), with a projection of reaching 18.62 in 2021 (Polidoro et al. 2021). The Brazilian commercial farms have a recent increase due research and economic incentives for ICLS adoption with a predominance of crops such as soybeans, beans, corn, and rice and livestock mainly with beef cattle. Besides, most smallholders traditionally practice ICLS, often integrating diverse cultures with dairy cattle, swine, and poultry (de Moraes et al. 2014; Gil, Garrett, and Berger 2016). On the other hand, in France, there was a remarkable decline in ICLS related to Common Agricultural Policy (CAP) incentives, market globalization, and lack of human resources (Ryschawy et al. 2013). ICLS is mainly developed in areas less favorable to agriculture or where the production of cash crops is less profitable (Ryschawy et al. 2013). However, there remain some perspectives of adopting integration at the landscape level as complementarity may be achieved between specialized farms (Moraine et al. 2014b).

This article seeks to understand the position of advisors and the resources they mobilize in what we call "double transition" of 1) advisors in their profession (facilitating vs. advising roles) and 2) helping the farmers to adapt to ICLS. It particularly focuses on barriers and levers faced by advisors to promote a transition towards more reconnection of crop and livestock at farm and landscape level. We first present our methodology that is based on interviews with ICLS advisors in Brazil and France. Second, we analyze advisor's profiles and main skills and activities. Then we discuss barriers and levers that were perceived by interviewees in mirror with literature. We conclude with an outlook that resumes the main perspectives to strengthen advising in ICLS, as well as its development.

2. Material and methods

2.1.Sample strategy

We aimed to practice semi-structured interviews to exchange with advisors on their perceptions and motivations (Adams 2015). We selected advisors that are currently involved with farmers in ICLS. Diversity was sought relating to their roles (field advisor or project manager), the main thematic of work (e.g., forestry), and geographical distribution (Table 1). We sampled 20 advisors: 10 profiles in both Brazil and France.

As advisors are generally specific in animal or plant production and ICLS advisors are not very common, we used a snow-balling technique for sampling (Goodman 1961). We started contacts with advisors who were already in the network of the authors of this work (all ICLS researchers) and then proceeded the contacts by the suggestion of the fist interviewees.

2.2.Semi-structured interviews

The semi-structured interviews were based on an interview guide (appendix 1) composed of five topics: a) professional trajectory; b) mobilized knowledge; c) experience in advising on integrated systems d) methods and tools for advising on integrated systems; and e) classification of the major limitations for the adoption of ICLS. Interviews were conducted between September 2020 and February 2021. Eight interviews were conducted face-to-face (5 in France and 3 in Brazil) and 12 online in video calls (5 in France and 7 in Brazil) due to physical distances and the COVID-19 pandemic. They lasted between 1-2 hours and were all recorded (totalizing 26h) and integrally transcribed in each of the original languages (Portuguese and French).

2.3.Data analysis

An inductive qualitative content analysis was performed (Elo and Kyngäs 2008) for content analysis of the advisors. Interviews were qualitatively coded to identify recurring themes with the n-vivo software (Welsh 2011). The codes were derived from the main points that emerged during the interviews and grouped initially from the structured topics in the interview guide (Appendices 8.1). We then plotted six mind maps

(1 – advisors´ profile and trajectory, 2 - sources of information 3 - goals with farmers, 4 - professional motivations, 5 – levers and barriers for ICLS, and 6 - tools, methods and projects mobilized in ICLS) for an overview of the main perspectives as Perrin et al. (2020), one example is presented in Appendices 8.2.

3. Results and discussion

3.1.ICLS advisors’ diversity of profiles and trajectories

3.1.1. Profile of respondents

Respondents were on average 35 years old in France and 46 years old in Brazil, ranging from 28-59 (Table 1). A quarter of respondents were female and the remainder male. In France, the main thematic of work was related to crop and dairy cattle, and in Brazil, beef cattle and ICLS. Some excerpts from interviews will be presented to illustrate the results and will be referred to the advisors with the code "F/B + number" as shown in tables 1 and 2, being F1-10 corresponding France´s advisors and B11-20 advisors from Brazil.

3.1.2. Background of respondents

Interviewees had a different background in integrated systems. Regarding college background there were at 55% Agronomists, 25% Animal Scientists and 10% Veterinaries. On average, advisors had 14 years of experience (~9 years France and ~19 years Brazil), ranging from 4 to 35, with most of this experience based on ICLS activities. Regarding the animal species involved in the production systems, there was a prevalence of 19 out of 20 of beef cattle. Beef cattle were predominant in the Brazilian cases whereas in the French cases, dairy activities balanced it. Farms with small ruminants were also frequent for 50% of the advisors in France. The cash crops had greater diversity in both countries, with the most frequent crops being soybean, and corn cultivation (Table 1).

We grouped the activities from the interviewees into i) project managers, as the group of professionals who coordinate specific projects and/or coordinate a group of advisors; and ii) advisors, as professionals who work only directly with farmers. The project managers usually have the responsibility to motivating the group of advisors, provide knowledge resources to them, and looking for the development of the current and future projects (Blum, Cofini, and Sulaiman 2020). The number of farms served by project managers was represented by the sum of farms served by their teams of advisors (Table 1). We called all interviewees "advisors" over the paper to facilitate reading and only detailed as "project managers" where the content was related to the role.

All interviewees belonged to private advisor organizations according to the definitions proposed by Prager et al. (2016), where considered “private advisory” is the nature of organizations that provide advice not couplet with the sale of agricultural commodities. The authors also consider “commercial” as the activity of offering advisory services for a fee. In this sense, the respondents had activities that range from the public (through government projects or funding institutions), a blend of commercial and public (with subsidies), and only commercial (farmers paying directly for advising).

Table 1. Profile of the interviewees with the main thematic and actual role. * Farms served indirectly through project managers (who have a team of advisors) or group animators. NP=not pertinent; D=Dairy Cattle; B=Beef Cattle; S=sheep; G=goats.

	Description									
Advisor	Region	Main thematic	Interviewee activitie	Gender	Age	Years of experience	College	Farms currently advising or in the projects	Crops	Livestock
France										
F1	Southern	Crop	Advisory	M	28	4	Agronomist	8 regularly + 50 sporadically	wheat, soybeans, corn, faba bean, barley, sunflower, rapeseed, lentils, and forages	BDS
F2	Southern	Crop	Project Manager	F	42	10	Agronomist	300*	Corn, wheat, sunflower, mostly. A little soy, a little sorghum, peas, field beans	BDS
F3	Southern	Forestry	Advisory	M	30	6	Forest Management	40	Forest, cereals	BS
F4	Western	Machinery	Project Manager	F	28	3	Agronomist	NP		BD
F5	Southern	Crop	Advisory	M	29	4	Agronomist	300*	wheat, spelled, barley, flax, sunflower, forage legumes	BSG
F6	Northern	ICLS	Project Manager	F	30	5	Agronomist	22*	winter barley, rapeseed, forage corn, grain corn, alfalfa, meslin	BDS
F7	Northern	Dairy Cattle	Project Manager	F	35	15	Animal Scientist	60*	wheat, beet, rapeseed, corn	D
F8	Northern	Dairy Cattle	Advisory	M	32	10	Agronomist	100	corn, fodder beet, meslin	BD
F9	Northern	Financial Management	Advisory	M	41	14	Animal Scientist	13groups with 210 farmers		BD

F10	Eastern	Dairy Cattle	Advisory	M	53	20	Agronomist	30 regularly + 150 sporadically	rapeseed wheat barley, maize	BDS
Brazil										
B11	Southern	ICLS	Project Manager	M	43	20	Animal Scientist	3000*	corn, soybean, cereals	BDS
B12	Southern	ICLS	Advisory	M	31	8	Agronomist	15	soybean, and rice	B
B13	Southern	ICLS	Project Manager	F	59	35	Animal Scientist	110*	corn, soybean, wheat	BD
B14	Midwest	Financial Managemen t	Project Manager	M	45	22	Animal Scientist	400*	soybean, corn, sugar cane, wheat, rubber, fruit	B
B15	Midwest	Beef Cattle	Project Manager	M	55	31	Veterinary	400*	soybean, corn, sugar cane	B
B16	Central	Fertilization and irrigation	Project Manager	M	59	29	Agronomist	21*	corn, soybean	B
B17	Southwest	Beef Cattle	Project Manager	M	31	8	Veterinary	9	corn, soybean	B
B18	Northern	Beef Cattle	Advisory	M	43	13	Agronomist	40*	corn, soybean	BD
B19	Midwest	Beef Cattle	Advisory	M	47	24	Agronomist	2	soybean and corn	B
B20	Northern	Beef Cattle	Advisory	M	44	6	Agribusiness Technologist	5	corn and sorghum for silage	B

3.1.3. Professional motivations of advisors

The professional motivations were most related to farmers´ wellbeing and the achievement of technical development and evolution on the farms according to 13 advisors (F1, F3, F4, F5, F6, F7, F8, F10, B11, B12, B16, B17, B20). Creating concrete things on the field was also considerate as important to advisor's professional motivation. For instance, B17 highlighted that he also appreciated his role in helping to motivate farmers to go further from their "initial level" for more: *"[what] motivates [me] every day is to always think, seek and encourage farmers to grow more as if I was a personal trainer wanting to make a person who just walked or just run a marathon."*. A project advisor emphasized its motivation towards developing a group spirit that works and leads to concrete actions (F9).

Two French advisors stressed their motivation related to the fact that they have no commercial role and can be "just advisors" referring to the fact their work was not coupled with selling inputs or buying outputs (F4, F8). B14, a project manager, also mentioned the importance of generating value and learning: "*what makes us wake up early all day is really increases the capacity to generate value, for whomever, it is [farmers and employees], for whoever has entered there [in each farm], including for us technicians who naturally have the value of remuneration, but I think the value of learning is amazing*.".

3.2. Four mains advising activities and a large panel of knowledge sources and tools

As mentioned during the interviews, ICLS advising requires multi-activities for helping farmers to set effective crop and livestock coupling. We clustered the main activities that emerged in the interviews and a reflection on what would be involved. Four groups (blue boxes - Figure 1) of activities performed by ICLS advisors were framed: communicate and facilitate famers´ groups, support ICLS co-design, gather ICLS knowledge and mobilize tools, and assist on-farm transitions. We explore over the next sub-sections each 'advisor's activity.

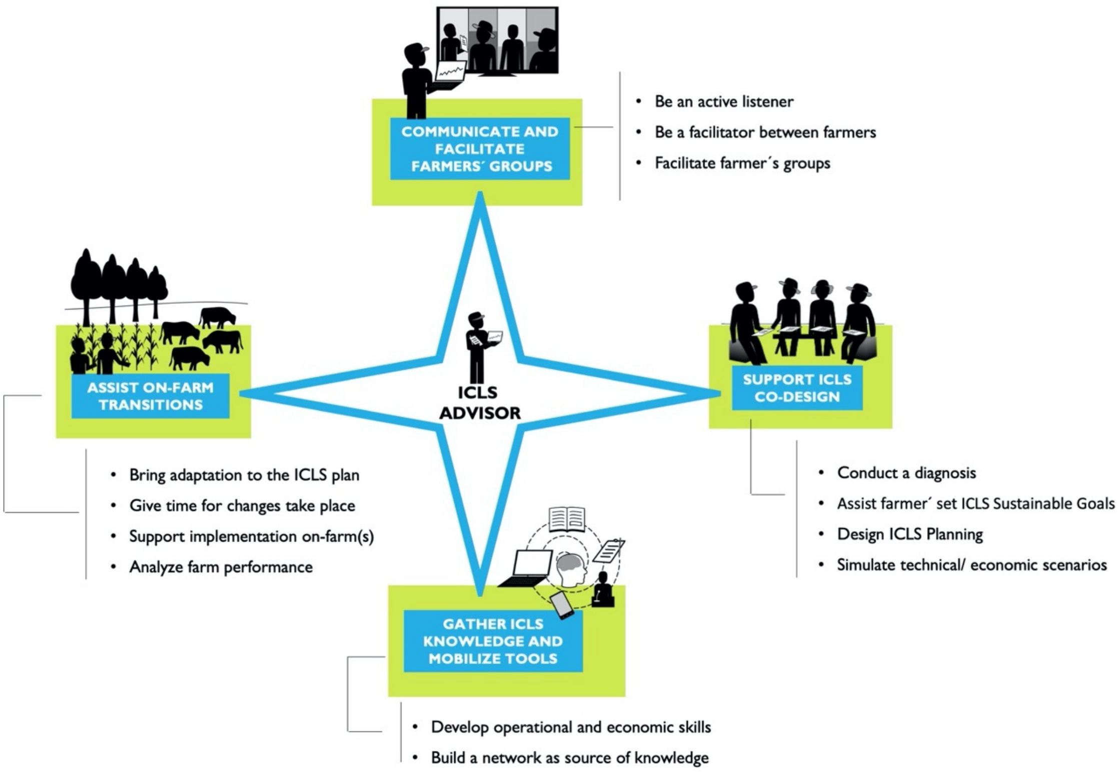

Figure 1. Four clusters of the main activities performed by ICLS advisors.

3.2.1. Communicate and facilitate farmers' groups

Communication is a central activity for advisors as most of their work is based on exchanges with farmers and other advisors that lead to knowledge diffusion. Three advisors mentioned the general need for communication skills, particularly regarding the way they interact with farmers (F1, F2, F3). For instance, they mentioned **active listening** (F9) to better understand farmers' goals and motivations. B17 highlighted the recent change in his company's work posture *"We used to be much more imposing, from about four years ago we have changed our way of acting a lot and we are listening to the producer's desires a lot, where he wants to go, what his dream is, his objective there with that farm with that business."*

The second advisors´ activity we grouped is to be a **facilitator between farmers**, that is essential to developing an ICLS co-design. In this context, B11 stressed the importance of an impartial and conciliatory posture to help crop and livestock farmers be into a joint project by thinking in the system.

As well as project managers, advisors also report dealing with the **facilitation of groups** around specific themes (e.g., in France, GIEE - Economic and Environmental Interest Groups, pasture management thematic groups, and phytosanitary reduction). In this context of leading groups of farmers, animation skills were related as important for the interviewees. B13 illustrated their experience with communication tools for helping in group animation interact as *"we [project managers] form a WhatsApp group and are always exchanging information, they [farmers and advisors] interact, they put photos of what they are doing, when the advisor goes [to on-farm visit] there they take pictures of them and the advisors doing some activity, looking the field and they are very active in these WhatsApp groups. And I think that these groups help to keep these groups mobilized, and then they increasingly evolve on the issue of implementing the ICLS system."*

3.2.2. Support ICLS co-design

Even though interviewees didn't explicitly mention it as such, they practice co-design in most of cases. They usually first **conduct a diagnosis of the farm** as B12 illustrated "*when we start a job (...) in the integrated system, we make the diagnosis (...) My first step is to understand things as they are today*".

Meanwhile diagnosing, comes the stage to help farmers **in setting goals**. Most of the goals that interviewees targeted with farmers were related to the dimensions of sustainability (i.e., economic, social, and environmental). Economic results were the main objective to achieve as mentioned by 14 advisors (F1, F2, F3, F4, F5, F6, F8, F9, F10, B12, B14, B15, B19, B20). Three advisors underscored the need to show some farmers short-term returns to convince farmers of certain changes (F3, B11, B12). One example was presented by F3 who usually proposes to farmers start by planting trees in livestock farms as a source of straw bedding for livestock to have short-term economic return compared with wood products that can take decades to be reexplored and have a financial return.

Economic sustainability was cited as the key to the other sustainability factors, as mentioned by B19 *"with the money in your pocket, it is possible to improve people's management, pay the employee better, training him, the [employee access to] a decent house and internet. Conserving the environment, which is very expensive!"*. According to project manager B13, it is crucial to disseminate ICLS projects through economic bias, as farmers have prejudice with the approach of environmental sustainability.

Environment concern was described as a recent issue, mostly due to regulation and financial incentives. In the environmental dimension, also the search for the autonomy of the farms, mainly in protein, was mentioned by three advisors from the north of France due to the high purchase price and the import dependence (F7, F8, F9). The search for arrangement in farms with ICLS was highlighted by manager B11 in "*[we] search for harmonization between activities that share land use, agriculture, livestock and the different activities within livestock and within crops*".

Aspects related to social sustainability were also presented as objectives. Like the search for farmers to live off their profession and live well, with pride and pleasure. The creation of values, the network of relationships, new skills and empowerment were also mentioned. An example of empowerment is about farmers´ convictions vis-à-vis salespeople *"There are farmers who are going to tend to change their ration [for dairy cattle] 15 times because every time there is a new food seller who comes to the farm. The idea is to allow them to think* *themselves about their ration, their rotation and to orient themselves towards their objectives.”* F6.

Once ICLS goals are set, is necessary a plan to help farmers achieve these goals and strengthen the farm. On way to start developing a plan is through the **design and evaluation of scenarios** with tools for helping quickly visualize the impact of the designed propositions (Ryschawy et al. 2014; Pissonnier, Dufils, and Le Gal 2019). Two co-design ICLS with groups of farmers were cited by advisors. One is “Farm Coaching” workshop set in southern Brazil (B11, B12, B13) where a tool is used to simulate the economic result of ICLS designed scenarios. Other was ColInnov project set in northern France (F6, F8, F9), with a methodology that start from ICLS co-design workshops with specific tools and, for example, accessing the designed scenarios with “an economic simulation using a whole bunch of references” (F6).

3.2.3. Gather ICLS knowledge and mobilize tools

In addition to their specific college training the advisors mentioned that **developing operational and economic skills** are important to their day-to-day work in ICLS. Six advisors cited the need for practical experience to understand operational management (F5, F6, B11, B15, B17, B19). In this sense, to keep in touch with the practice and learn by doing, two advisors regularly work on-s-farms activities besides working as advisors (F1, F3). The practical need exposed by some advisors corroborates recommendations from (Rachael D Garrett, Gil, and Valentim 2014) to help ICLS adoption with colleges providing technical and financial courses about whole-farm agricultural management, approaching ICLS complexities. The operational activities on ICLS farm requires a good planning to avoid competition between crop and livestock production by machinery, human resources, and budget as there is interactions in space-time.

Considering the importance of economic issues in the main goals to achieve, four advisors noted the lack of college training in economic aspects, such as the economic impact of the agricultural practices studied (B12, B15, B16). In France, a good understanding of the implications of farming subsidies from the Common Agricultural Policy (CAP) is also required (F1). The lack of approach to economic aspects in college is somewhat worrying since the economy is one of the pillars of sustainability. Even more to calculate the potential benefits of economic performance and risks of ICLS concerning specialized systems (de Oliveira et al. 2014).

Networking is a crucial source of ICLS knowledge for advisors. So, advisors need to establish a strong network around them. They are in inter-relation with their peers to get specific information (on farms, technical, organizational, etc.). When asked where they look for information, questions, and updates, the first source cited was "other advisors", whether from the same company/institution (F1, F3, F4, F5, F6, F7, F8, F9, F10, B11, B12, B14, B17) or other institutions (F3, F4, F5, F6, F7, F8, F9, B16, B17, B18, B20). Advisors also mentioned the search for an interdisciplinary exchange (livestock advisors x crops advisors). For example, F1, who is a crop-advisor, said he asks the help of livestock advisors when needs animal nutrition knowledge. Advisors need to be open to farmers´ needs and experimentations. Seven advisors stressed the importance of the empirical knowledge of farmers (F1, F3, F5, F6, B11, B16, B19), which, according to B11, is not always well recognized by researchers and advisors.

In addition to using their network of peer-advisors and farmers, 7 Brazilian advisors sought more information through research groups or researchers as ICLS knowledge sources, with which they reported a strong connection with sharing the conduction of trials and research and farm results (B12, B13, B14, B15, B16, B17, B18). French advisors would rather search for scientific information through internet searches or technical magazines (F3, F4, F6, F7, F8, F9, F10). Advisor F7 reclaim lack of time to explore bibliography. On the other hand, F6, as project manager, said having time allotted especially for link research and literature directly to advisors. Internal training and technical events were also identified as sources of information and exchanges with researchers and advisors for updates on recent results (F1, F3, F4, F8, F9, F10, B11, B12, B15, B17, B20). Social media, such as Facebook, YouTube, and Twitter, were increasingly present, especially since the pandemic of COVID-19, providing news, disclosures, and information (F4, F5, F6, F7, F8, F9, B11, B19).

Networks of advising connected to public research and education are crucial for avoiding distance from new knowledge even more in private organizations where in there are lower investments in research and development (Prager et al. 2016). Therefore, was interesting to notice the interactions pointed in the interviews and the use of communication tools for this quickly and periodically exchanges.

3.2.4 Assist on-farm transitions

To assist on-farm transition the **flexibility and adaptation** are crucial to ICLS advisors. F4 recalled that the agroecological transition is not linear, which changes the skills needed by advisors and requires them to adjust to the evolving situation. An interviewee stressed the importance of being patient (F2), and understanding that **changes take time**, as well as knowledge diffusion. It thus implies that advisors find a balance between responding to farmers' current needs and acceptance of changes in court-term and looking for long-term deep changes. B14 perceived a learning curve based on his company database (~1,100 farms being ~280 ICLS), where farmers who adopt ICLS start with low economic results than average specialized systems, *"but after integration is established, they completely detach [the economic results]1 from the average"*.

One method pointed out by three advisors as proposed to farmers to start on-field implementation is the use of pilot areas (F1, B18, B19). Pilot areas can be strategic to test new practices with more control and lower risk for the entire system if it doesn't work.

The co-design workshop ColInnov´s (presented at 3.2.2.) are followed by actions to assist groups of farmers in the transitions. The activities include coaching meetings (for motivating the action plan continuity), discussion meetings, feedback meetings, operational visits, and individual tours on-farm. And after the Farm Coaching workshop in Brazil, some farmers participate in ICLS extension projects (that may include on-farm visits and on group activities) and others hired private advising to set on-farm their action plans.

3.3 Levers and barriers for actual advisors become advisors that favorize ICLS development

In this section we will present the elements that are barriers or levers to actual advisors become advisors that favorize ICLS development in five dimensions. We grouped the elements as a pull factor that are top-down (politic and economic level) and push factor that is bottom-up (advisors´/ farm level) as the format proposed by Geels (2011).

Table 2. Push and pull factors as barriers or levers to ICLS advising development

Dimension	Barriers	Levers
ICLS as complex systems 3.3.1		Pull factors: • Subsides to allow time to an advisor to train themselves and discuss with farmers
	Push factors: • ICLS is more complex than specialized systems • Lack of advisors with a systemic approach • Lack of technical and economic references to ICLS	Push factors: • Encouraging advisors' exchanges between crop, pasture, and livestock specialized advisor • Developed specific technical and economic references to ICLS • Adapted tools for co-design ICLS
Training advisors in ICLS 3.3.2	Pull factors: • Structural specialization of Universities, Research Centers, and Institutions of extension • Current training on a variety of specialized thematic without learning to connect them	Pull factors: • Rethink the ICLS training on college so that they have more knowledge • Opening to a systemic vision through training/ Training in holistic view and ICLS planning • Financing advisers' time so that they can work together without having to learn everything (a crop advisor with a livestock advisor)
Sensibilization around ICLS and the Overspecialization of farms 3.3.3	Pull factors: • Farmers lack awareness of ICLS potential benefits	Pull factors: • Encourage diversified farmer network to enhance sharing skills on ICLS and learn from their knowledge as an advisor
	Push factors: • Farmers not familiarized with the systemic approach of ICLS advising • Other advisors with different discourses (e.g., advisors selling products)	Push factors: • Awareness of farmers and other advisors of ICLS thought field days and training
Trust and collaboration issues 3.3.4	Push factors: • Relationship between crop and livestock farmers (low contracting, poor communication, individualism, lack of trust)	
Broader context 3.3.5	Pull factors: • cultural aspects related to farmer's background • Context of the disappearance of animal production	Pull factors: • Access to credit for farmers who want to adopt ICLS • Cooperatives (CUMA) • Political incentive to ICLS qualified extension services • Economic context unfavorable (that forces a search for alternatives to specialization)

3.3.1 ICLS are more complex systems

ICLS more complex than specialized systems and this can be a barrier to adoption (F8). In this sense, B14 noticed that ICLS brings more complexity to management and the better outputs will not be achieved for all adopters as he s *"over these 20 years we have followed around 1,110 farmers here. Of these 1,110 farmers, 283 are integrated […] farms with integration on average have less money than farms without integration […], it gives a very clear sign of the complexity of the process, on the other hand, when you analyze the best [economical ICLS] farms […] you find integrated farms delivering better results, that is, the professionals [farmers], who arrived to manage and to execute, integration was really good."* B14.

a) Lack of advisors with a systemic approach

According to five project managers, advising in ICLS requires a systemic view of the farm, representing a challenge to find advisors with this skill (F2, B11, B13, B14, B17). Systems thinkers usually view a situation or problem through different perspectives and try to address various solutions as necessary to adapt to changing situations (Church et al. 2020). This echoes the evolution of agroecology consulting with the barriers linked to the current locking of the dominant regime (conventional agriculture and knowledge transfer) put in place. Our findings are in line with previous studies on other examples of agroecological systems such as conservation agriculture (Prokopy et al. 2019) or agroforestry or more generally agroecological transition (Vanloqueren and Baret 2009; Coquil et al. 2018).

a) Tools and methods to ICLS design and analysis

Looking specifically to tools for analysis of ICLS, 7 advisors said they lack systemic tools. Some examples of adapted spreadsheets to the ICLS analysis were: one for or planning the use of animal production effluents for fertilization (B16); one for simulate profit from different technical choices of ICLS systems (B19); one for calculating straw/manure exchanges (F4, F6, F8), and one for forage scale for price calculation for grassF1, F8). F2 and F6 highlighted the importance of avoiding tools that are too complicated to use and, to that do not happen, F4 proposes to involve the animators who will use the tools in creating the tools.

Seven advisors noticed the lack of systemic tools and methods with a pedagogical approach to assist in ICLS co-design with farmers (F1, F3, B11, B12, B14, B17, B19). Tools are important to help farmers visualize, manipulating and exploration for example (Ditzler et al. 2018). B11 illustrated is as *"We [advisors, researchers] launch a scientific graph with a parable that says absolutely nothing to farmers […] this is extremely unpleasant, not practical for absorbing knowledge. Nothing practical!"*. As an alternative the lack of pedagogical approaches B15 suggested training advisors and farmers with a method based on active learning in small groups, the Problem-based Learning methodology (Yew and Goh 2016).

3.3.2 Training advisors in ICLS

As the agricultural courses lack of system approach to farm management, then students (i.e. future farmers or advisors) are not being trained to address complex agricultural issues as ICLS (Jouan et al. 2020). In this sense, there is a huge need for properly trained advisors (and the training should start during college), that understand and manage the complexity of space-time coupling in ICLS. Basic economic training is also necessary for advisors to assist farmers to simulate and access designed scenarios as proposed by Ryschawy et al. (2014). Besides, training in system thinking is necessary to advisors help farmers addressing the impact of practices on the system (Jouan et al. 2020).

Two advisors pointed out that as ICLS is more complex so to finding someone who just left college with all these skills is not easy (F2, B17), similarly to the lack of training in a system view (B11). B13 explained that it is necessary to reconcile advising skills with ICLS knowledge *"the training in ICLS is not easy for you to have, it is that not everyone who graduates has an advisor profile, still has that, and sometimes you have an advisor for example, that you see that he has deep knowledge of ICLS, but he has difficulty to relate to the farmer."*

3.3.3 It is necessary to sensitize farmers and advisors with ICLS approach

a) Lack of ICLS awareness from farmers

Two advisors pointed farmers´ lack of awareness of ICLS is also a barrier to integration in B11 and B12 experiences. And this lack of awareness could be related to a recent interest in integrated systems in Brazil and still few farmers adopted, especially in some regions as northern Brazil (B14). As ICLS are regaining their importance (Carvalho et al. 2010), farmers still need to be sensitized about potential interactions and synergisms they could benefit from ICLS beyond diversification (Bonaudo et al. 2014).

Another barrier pointed is that farmers usually interact with advisors whose role is to answer specific questions or indicate products, so they are not familiarized with ICLS advising approach. For example, F6 noticed that farmers do not identify the adviser role as more strategic, more systemic, they usually just ask punctual questions. And B13 says *"the farmer himself sometimes has difficulties to understand that the advisor is there to guide the integration and not individually just an isolated activity"*.

b) Lack of ICLS awareness from advisors

One of the barriers set up by five advisors is the fact that other advisors – who also interact with the same farmers - are not aware or sensitized to integrated production and therefore have different discourses (F7, F8, F10, B13, B17). In this sense, F5, F9, B13, highlighted that the common is only crop or livestock advisory and that there is a lack of advisors with a systemic approach. The F6 also highlights the structural issue of institutions of extension *"So it's a little difficult to make the connection between the guys [livestock advisors and crop advisors] and even them who are two desks apart, they don't necessarily have the reflex, the time or anything to go knock on the door."* In addition, there may be a conflict of interest with advisors selling products, such as *"Between a cooperative that will sell feed and me who will sell advice, we are not, perhaps, on the same length"* F10 and *"advisors that exist in the market, most of them have a relationship with a company of inputs whatever it may be. And this directs the farmers to some issues as product bias"* B13.

3.3.4. Trust and collaboration issues

A barrier to ICLS is the relationship between crop and livestock farmers, whether at the farm level (as is often the case in Brazil) or on a territorial scale (as seen in the French context). When there are at least two people who manage different activities there are some challenges that are posed such as communication between them (F8, F10), trust (F4), individualism (B11), the need for contracting that is usually not done (F5) and some logistical challenges between them (F2, F4, B17, B18).

3.3.4. Highly different cultural and political context has influenced ICLS status

Regulations, credit mechanisms, and supply chains are often focused on single commodities, making financing and marketing of ICLS challenging (Gil et al. 2016, Cortner et al. 2019). Also, economic advisors (i.e., bankers, creditor etc.) can impact the acceptance of ICLS projects if they are not aware of benefits and risks of it.

In the French context, F9 talked about a significant decrease in livestock and specialization in agriculture. F4 also addressed this context that drives the disappearance of animal production and the difficulty of going against it. Ryschawy et al. (2013) have highlighted major factors explaining the long-term decrease of crop-livestock systems in the European context. First, the political and economic context and, in particular, the European Common Agricultural Policy (CAP) and market globalization associated with a decrease in workforce availability were identified as drivers of change that favored the specialization process. The survival of some mixed crop-livestock farming systems was allowed nevertheless by farmers' choices and values opposed against these driving forces. More recently, the CAP of the European Union, rewards the introduction of legumes, which encourages complementarities between crops and livestock (F5, F7). Also, subsidies from local associations for agroforestry serve as incentives for the insertion of the forest component (F3).

There is a recent re-integration dynamic in the Brazilian context at country level, notably encouraged by research initiatives from Federal Universities and EMBRAPA – the Brazilian National Agricultural Research Institute (Rachael D Garrett, Gil, and Valentim 2014; Gil, Garrett, and Berger 2016). Also, a government Plan for Low Carbon Agriculture (ABC) that provides subsidized loans for the restrictions on native vegetation clearing fosters farmers' adoption of ICLS to increase production on the agricultural land area available (Rachael D. Garrett et al. 2020; Cortner et al. 2019). Four advisors have highlighted a favorable context for access to credit (B14, B18, B20). But B11 still pointed to the political will as being necessary to help the adoption of ICLS on a large scale, focusing on implementation with qualified extension services, which is in line with Garrett et al. (2020 highlighting a favorable context for ICLS adoption in Brazil.

The cultural aspects of farmers were mentioned as a huge barrier (F1, F3, F7, F8, F10). The background of farmers can also be a barrier to ICLS, be it a background of livestock (B14, B20) or crop (F2, B13, B18) and that can also influence the joy by each activity. F2 further specifies that there is an image negative of livestock as an old and heavy activity. In terms of culture, lifestyle preferences for either crop or livestock management based on family experience and seasonal labor requirements and links between personal identity and current farming systems may limit adoption among certain individuals (R.D. Garrett et al. 2017; Ryschawy et al. 2013; Cortner et al. 2019)

Collaborative arrangements beyond the farm level have been mentioned in France. F7, F8, and F10 mentioned the fact that in their region - northern and eastern French - there are already many exchanges of straw (to make bedding for cattle) for waste (mainly due to an excess of nitrogen production). In France, Agricultural Material Exchange Cooperatives (CUMA) represent a lever for integration on a territorial scale because they are structures with an organization for sharing machinery, workforce, storage, forage drying and methanization (Lucas, Gasselin, and Van Der Ploeg 2019; Asai et al. 2018). Therefore, they can serve to mediate exchanges between crop and livestock farmers (F4).

4. Outlook and conclusions

Our inductive analysis is a promising first insight into adviser perceptions and motivations toward ICLS adoption in France and Brazil. The combination of different ages, backgrounds and roles brought a unique wealth of information to this study. We found a high level of motivations of advisors to coach farmers for greater adoption of ICLS, develop system thinking and even train themselves while gaining experience on the topic. In this sense, Klerkx (2020) further highlights a new trend of internationalization of advisory systems, so we encourage to analyze more transversalities from different contexts that may be useful as a portfolio of options to develop ICLS advising.

One common point in our sampling is that all interviewed were very well qualified and dedicated to training on ICLS, even though they did not have all the tools, skills, and knowledge they needed to properly coach farmers. Coping with these barriers would thus require major changes in the advising context and highlight some research avenues for the future.

First research avenue for ICLS advising: from knowledge transfer to knowledge exchange with coaching and facilitating roles

A deep understanding of "advisors´ world" including their identity and needs was pointed as key factor to enable advisory practice change to effectively help farmers face emerging challenges (Nettle, Crawford, and Brightling 2018). In this sense, the group of questions that we applied around professional motivations exposed how advisors identified themselves as a facilitator for farmer make transitions and associated their motivations directly to the fact that farmers achieve positive change. This identification of motivations is important because it can highlight for example the importance of advisors identifying themselves with roles as coaches, where they will be helping farmers with knowledge and tools to be protagonists of their decisions (Dockès et al. 2019). So, bringing coaching skills to advising in ICLS may represent a research avenue.

Besides the individual advising, in the context of farmers´ groups, the facilitation is considered as a required task to enable the reflection process in dynamic networks and one important feature to enhancing transitions towards sustainable agriculture (Moschitz et al. 2015). Therefore, facilitation is very important for ICLS since they are systems that usually involve more people with different perspectives who need to work together.

Second research avenue: continue developing relevant Decision Support System easily out scalable to various situations at different levels.

We propose a compilation of push and pull factors influencing advising in transitions towards sustainable ICLS (Figure 2). Garrett et al. (2020) highlighted the specialized nature of many research and advisory systems centered around individual crop or livestock commodities fails to provide adequate extension services to train farmers for new-ICLS management. In general, advising systems are implementing trials on specific crops and not considering the effects of crop-livestock integration. Some research laboratories having been dedicated to ICLS thematic and are providing substantial technical references and should continue in seeking complementarities and deep looing in long-term impacts (Franzluebbers et al. 2014; de Moraes et al. 2014; Carvalho et al. 2010). Besides some co-design tools and methodologies should be disseminated as Dynamix for territorial integration (Ryschawy et al. 2018), SIPAgame for ICLS awareness (Moojen et al., 2021 in prep.), CLIFS design, and assess ICLS scenarios (Ryschawy et al. 2014), SEGAE serious game for teaching ICLS (Jouan et al. 2020) and Forage Rummy board game to test local system possibilities (Martin, Felten, and Duru 2011).

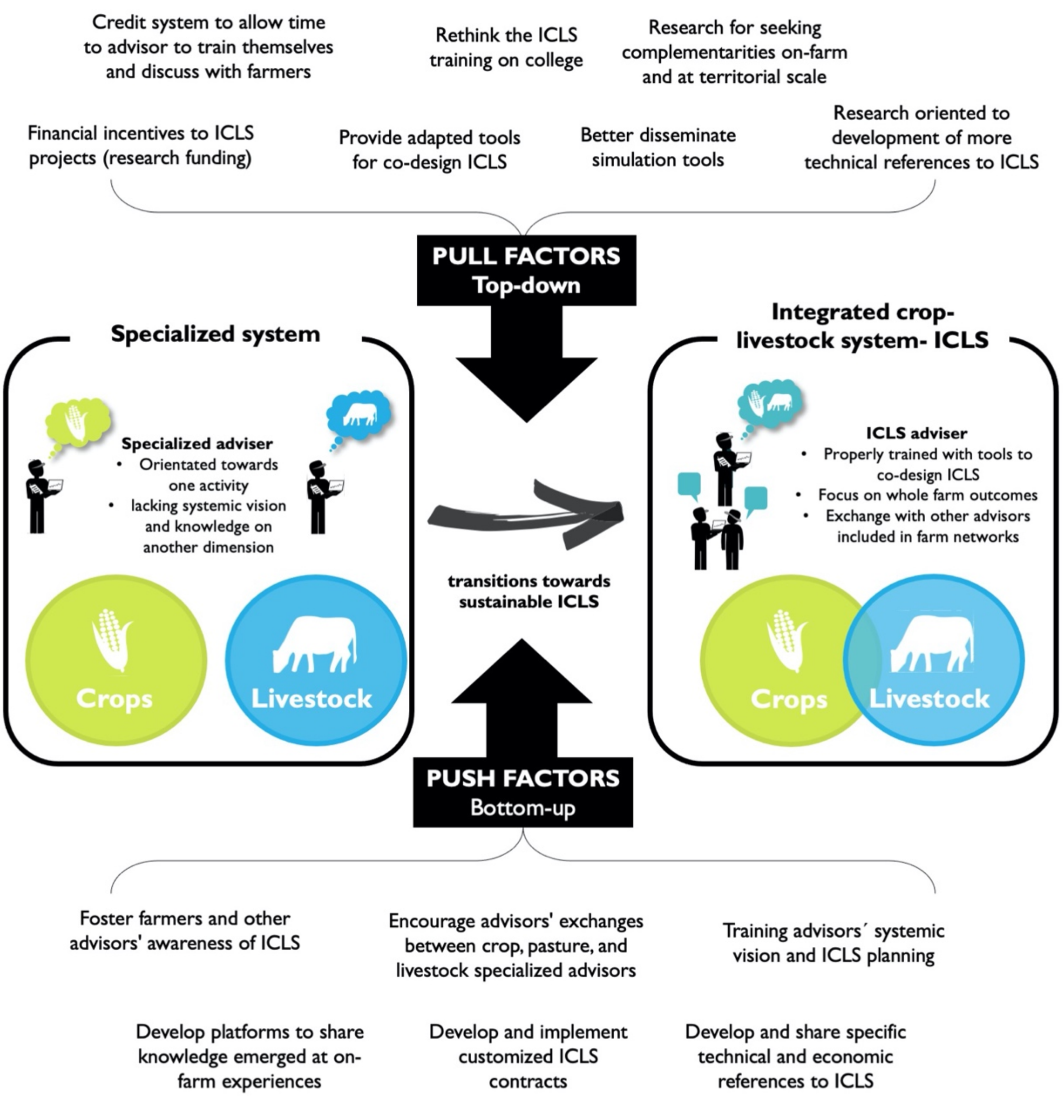

Figure 2. Pull and Push factors influencing advising in transitions towards sustainable ICLS.

The barriers seen at advisor levels call for a major change in the systems if we want to mainstream ICLS.

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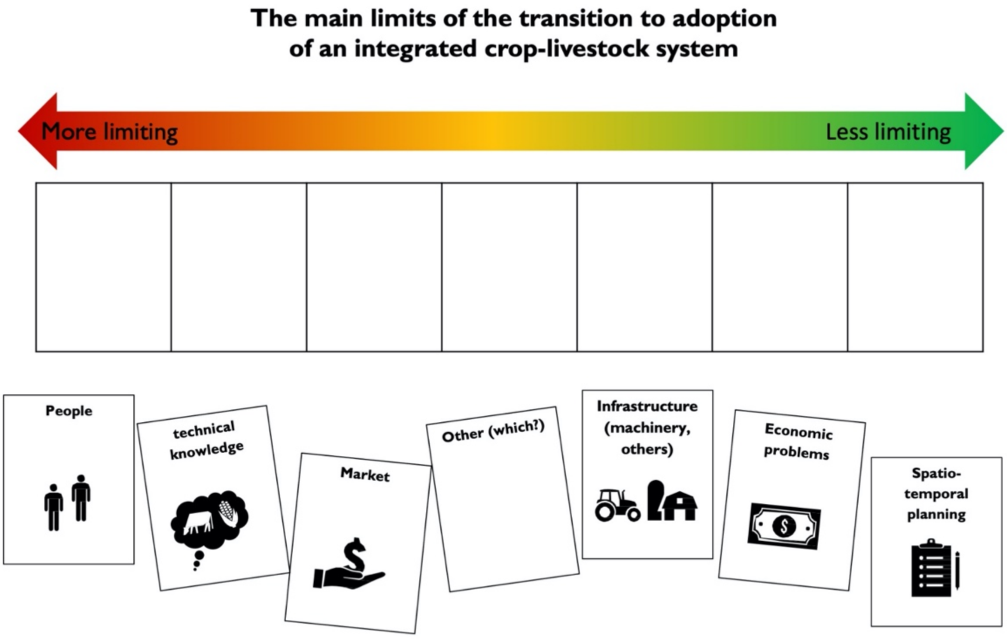
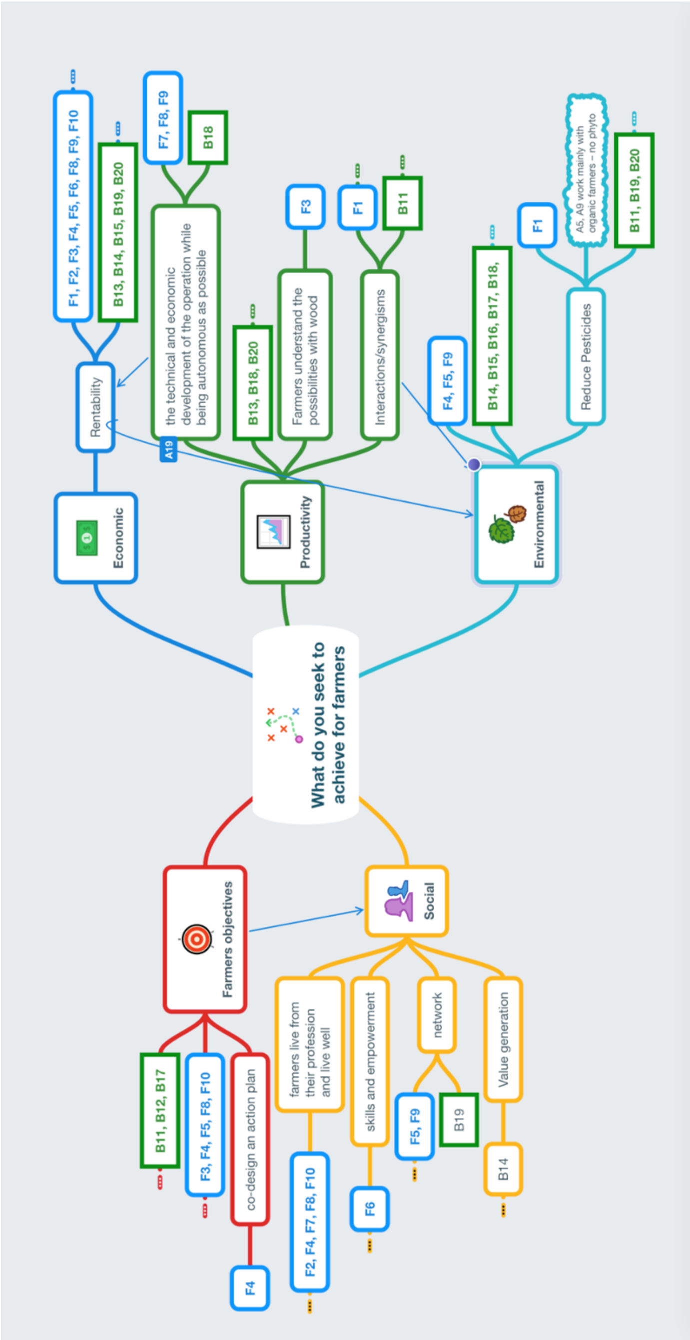
8. Appendices

8.1 Interview guide used

a) Professional trajectory
1. What is your training path? 2. What agricultural and animal crops are you working on? 3. How many years of experience do you have as an advisor? 4. How long have you been working with integrated crop-livestock systems (ICLS)? 5. How many ICLS farms are you working on advising? in which region where they located?
b) Knowledge mobilized
1. What knowledge do you mobilize? 2. What knowledge and skills, apart from your current expertise and your scientific disciplinary training, have you needed to learn and develop in order to advise farmers towards a sustainable mixed crop-livestock production? 3. To find new knowledge, what are your sources of information (other advisers, farmers' groups, researchers, YouTube, social or professional networks, specialized journals, etc.)?
c) Experience and strategies in ICLS advice
1. In your interactions with farmers, what do you seek to achieve for farmers? (Sustainability, money, peace of mind, technique, organization, reducing phytosanitary products or for the autonomy of farms or territories ...) 2. And what are your motivation as an advisor, what is it that matters to you? 3. What are the general obstacles to advising farmers with ICLS (at different levels: policy, trade, infrastructure, people, reflections)?

4. And what are the levers? (What are the options for resolving the constraints and challenges)?
d) Methods and tools
1. What are the main tools and methods that you mobilize for the adoption and management of sustainable ICLS (speech, technique, educational process)? Do you use specific tools? 4. What current tools and methods are you lacking? 5. What are the tools and methods dreamed of for you in the future from supporting farmers to mixed farming?
e) Based on your experience, consider in descending order the main limitations of the transition to polyculture-livestock systems adoption:


8.2 Example of mind map with a central question in the middle and five main group of ideas, with key words that represent the main ideas emerged in the interviews with advisors. F1-10 corresponding France´s advisors and B11-20 advisors from Brazil



CHAPTER V

5 CONCLUSION AND FINAL REMARKS

This thesis provides the firsts steps towards co-design and effectively implementing more sustainable ICLS at the farm level. The development of Farm Coaching proved to be effective in going through the deconstruction of the current mental model of agricultural specialization towards integrated systems. Thereby, it is encouraged to out-scaling the methodology by combining the technical approach to psychological support under sustainable transitions. Furthermore, the SIPA game proposed in Farm Coaching workshops to co-design scenarios to sustainably recouple crops and livestock at the farm level helped players in the communication and visualization of interdependencies during the co-design of ICLS. Finally, the interviews revealed barriers and levers of the ICLS on field level. Besides, the activities and the challenges from advisors' perspectives were summarized. In this sense, there is a huge need for properly trained advisors (and the training should start during college), that understand and manage the complexity of space-time coupling in ICLS.

5.1. FURTHER DEVELOPMENTS

Here a brief list of some improvements and next steps for this work that could be developed.

First, on the Farm Coaching:

- It is necessary to scale up the dissemination of the FC methodology through the training of more coaches, standardization of the tools used, and dissemination of the results.
- The methodology can be adapted to smallholders, by adapting the content to the production systems they such as dairy cattle or more diversified systems. Structuring workshops to be place closest to their farms and customizing the duration to fit into their routines. Also adapting the format of some dynamics to allow analphabetic contexts, if necessary. For that it is necessary projects for financing to enable the participation of these actors.
- It would be interesting to include the Farm Coaching methodology as the first step in ICLS extension projects. With a sequence of monitoring the levers and barriers to putting into practice the "action plans" of farmers.

Second, in terms of the SIPA game:

- It is necessary to incorporate an automated analysis of the impact of decisions on sustainability dimensions.
- With the potential of using the game in the faculties of agricultural sciences it was successfully tested, it would be essential to disseminate its use to more universities in the country and abroad. To this end, it is necessary to further standardize the game's application format and looking of how to assess its impact in players on the understanding of ICLS.
- The game could also have a version with more customizable parameters to be used directly in farm planning. As this version would requires more inputs, it would be important to be developed in parallel to the game as it is (i.e., where groups have the same default initial scenario).

Third, looking for more perceptions of ICLS advisors:

- The survey of perceptions of advisors could also be carried out in other countries in other dynamics of adoption / abandonment of ICLS, such as those in the United States and Australia.
- It would be important to investigate further the issue of advisors as mediators of integration between different farmers (livestock and crop farmers).
- Another important step would be to build an “information bank” with a compilation of ICLS projects to assist new advisors with parameters to them co-design ICLS projects with farmers.

5.2. PERSONAL REMARKS

The Grazing Ecology Research Group and the Integrated Crop-Livestock System Research Group, from which I was a member during the doctorate, are recognized for robust long-term research, validated in more than two hundred papers. Most studies were with quantitative analysis and guided considerable advances in understanding biological processes. In this context, in my master's degree, I worked with a database of one of the long-term experiments, so most of my bibliographies were searched directly in the group´s references. However, in the doctorate, the challenge was precisely to leave the "comfort zone" of the groups and go to qualitative research, with analysis of interviews. I interacted, listened, and learned with farmers, researchers, and field advisors from two countries in the world. In this sense, the network of relationships created through the CAPES COF-CUB project was fundamental for constructing what was presented in this thesis. In France, I could see several serious games being developed and tested, and I could exchange information about the limitations, challenges, and alternatives to develop the research and reflect on the following steps to be taken.

It is also important to highlight that SIA has opened its doors to study initiatives such as Farm Coaching and advisory on integrated systems. The company's proximity to the university brings a rich environment for exchanging information and building sustainable production solutions. It is rare to find consultants with a holistic view and guide farms without focusing on just one component: just crops or livestock. Even rarer is the concern for the people involved in the production and their dreams. I had to look for many bibliographies outside of agricultural technical data to understand psychological patterns related to trust and risk, for example. Moreover, to bring these theories and reflections of sociology and anthropology with agronomy technical issues to build this thesis.

With this thesis, I hope to inspire new Brazilian students and researchers to continue investigating the use of methodologies such as serious games as platforms for exchanging knowledge with students and farmers. I would also like to leave reflections on the curriculum in agricultural sciences and their compartmentalization. It is crucial to include rooms for connecting knowledge of production, finance issues, communication skills, advising, and animation of farmers' groups to have professionals increasingly able to design more sustainable production systems.

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6 APPENDIX

6.1 RULES OF THE JOURNAL *AGRICULTURAL SYSTEMS* USED IN PAPER 1 (CHAPTER II)

AGRICULTURAL SYSTEMS

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TABLE OF CONTENTS

DESCRIPTION

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Divide the article into clearly defined sections.

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- Name(s) of author(s)
- Affiliations
- Abstract
- Key words (indexing terms), normally 3-6 items
- Introduction
- Material studied, area descriptions, methods, techniques
- Results
- Discussion
- Conclusion
- Acknowledgements and any additional information concerning research grants, etc. • References
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- Tables
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6.2 RULES OF THE JOURNAL *AGRONOMY FOR SUSTAINABLE DEVELOPMENT* USED IN PAPER 2 (CHAPTER III)

1. MAJOR GUIDELINES OVERVIEW

Key instructions are summarized in the following table:

	RESEARCH ARTICLE	META-ANALYSIS	REVIEW ARTICLE
Word limit	< 8000 words		16000 words
Formatting	Times 11 ; 1.5 spacing, lines numbered		
Novelty	• should be clearly explained in the cover letter, the abstract, the end of the Results and Discussion section; the Conclusion section • should be stated precisely and objectively, for example using "Here we show for the first time that ...", or "This is the first...".		The interest of the review should be clearly explained in the cover letter and the abstract
Title	Short and informative, highlighting the novelty and the result of the study	Should end by ". A meta-analysis"	Should end by ". A review"
Abstract	< 300 words Should present: 1. Background/issues/hypothesis 2. Experimental 3. Results/novelty		< 300 words Should present: 1. Background/issues 2. Major advances and interest of the review
Sections	1. Introduction 2. Materials and methods 3. Results and discussion 4. Conclusion		Contents 1. Introduction 2. First section (no IMRAD structure) X. Conclusion
Results and discussion	A combined Results and Discussion section should be preferred		Not applicable
Figures and tables	< 8 . Figures should be preferred.	Not limited but total number should be justified	Not limited but total number should be justified
	Tables should preferably fit on one page		
	The introduction should include a color photo, named "Figure 1", highlighting the main topic of the article		
Declarations	All manuscripts must contain the following sections under the heading 'Declarations', to be placed before 'References': • **Funding** (information that explains whether and by whom the research was supported) • **Conflicts of interest/Competing interests** (include appropriate disclosures) • **Ethics approval** (include appropriate approvals or waivers) • **Consent to participate** (include appropriate statements) • **Consent for publication** (include appropriate statements) • **Availability of data and material** (data transparency) • **Code availability** (software application or custom code) • **Authors' contributions** (include appropriate statements)		
References	Must contain the DOI		
Supplementary material	The need for supplementary material section must be justified in the cover letter. Data should be preferably deposited in a repository		

2. TYPES OF ARTICLES

Agronomy for Sustainable Development publishes three types of papers: *Research articles, Review articles* and *Meta-analyses (systematic reviews)*. The findings should deal with both Agriculture and Sustainable Development: see Aims and Scope for specific topics.

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The manuscript must be accompanied by a **cover letter** containing:

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- the full first name (no initial) and last name of all the authors,
- a paragraph describing **why their findings are novel** (for research articles and meta-analyses) or **why**

  a review on this subject is needed,

- **a list of four suggested, international reviewers**. The suggested reviewers must have no conflict of

  interest with the authors; they should **not have co-authored previous publications with the present author(s)**. They must represent an international diversity. When suggesting reviewers, the Corresponding Author must provide an institutional email address for each suggested reviewer, or, if this is not possible to include other means of verifying the identity such as a link to a personal homepage, a link to the publication record or a researcher or author ID in the submission letter. Please note that the Journal may not use the suggestions, but suggestions are appreciated and may help facilitate the peer review process.

4. EDITORIAL PROCESS

Upon submission, articles enter the preselection process. At that stage, the general quality of the manuscript and its **compliance with scope and author instructions** are evaluated by the Managing Editor and the Editors in chief; the non-compliance being a cause for rejection. The articles pre-selected are then assigned to an **Associate Editor** and at least **two external reviewers**, in a **single blind** process.

The Associate Editor submits his/her decision to the Managing Editor, who communicates a final decision to the authors. When revisions are requested, the authors are asked to answer point by point each reviewer comment. The revised manuscript returns to the **same Associate Editor** and is eventually evaluated again by the same or by alternative reviewers. Upon acceptance of the manuscript, the journal requests that the authors provide a **short post** on their article, that will be published in the journal blog (http://ist.blogs.inra.fr/agronomy/). The purpose of this post is to convert the main research information into easily accessible language in order to be **understandable**

by the largest possible audience. This post must be accompanied by a relevant **photo in landscape format**.

At the production stage, it is the responsibility of the authors to carefully examine the article proofs. **No major corrections** such as change in authorship will be accepted at this stage.
No correction can be made after article online publication. If an error is identified after publication, an erratum should be required by the authors.

5. REQUIRED FORMAT FOR RESEARCH ARTICLES

General

Research articles should report the results of original research. The material should not have been previously published or submitted for publication elsewhere. Research articles should focus on one major discovery supported by 2-4 results.

Novelty

The novelty, or difference, of the major finding versus current knowledge **should be clearly explained** in: - the cover letter to the Editor-in-Chief;
- the abstract;
- the end of the Results and Discussion section;

- the Conclusion section.
Novelty claims should be made in an affirmative way, using for instance "Here we show for the first time that ...", or "This is the first...".
Only articles showing notable added value will be sent for in-depth evaluation.

English

All manuscripts should be written in high-quality American English. Non-English native authors should seek appropriate help from English-writing professionals before submission. The journal may ask authors to provide a certificate from an English language proofreading service, ensuring correct grammar and typographical error corrections (i.e., punctuation, spelling, inconsistencies...) to help authors present a clear and scientific message.

Sections

The manuscript should contain the following items (in the same order):
- article title
- full first and last names of authors with an asterisk "*" highlighting the corresponding author; postal addresses; e-mail address of the corresponding author
- Abstract (less than 300 words)
- List of keywords (maximum 10)
- IMRAD elements:

- **1. Introduction**
- **2. Materials and methods** (including subsections - 2.1, 2.2...)
- **3. Results and discussion** (including topical subsections - 3.1, 3.2...)
It is advisable to submit a combined Results and discussion section. However, if authors prefer to

submit two distinct Results and Discussion sections, they should justify this choice in the cover letter.
- **4. Conclusion**

- Acknowledgments
- Declarations: (*see section 11 below*)

- **Funding** (information that explains whether and by whom the research was supported)
- **Conflicts of interest/Competing interests** (include appropriate disclosures)
- **Ethics approval** (include appropriate approvals or waivers)
- **Consent to participate** (include appropriate statements)
- **Consent for publication** (include appropriate statements)
- **Availability of data and material** (*see in section 13 below what is expected here*)
- **Code availability** (software application or custom code)
- **Authors' contributions** (include appropriate statements)

- References (*see section 8 below*)
Other sections such as annexes and appendices are not accepted.

General presentation

The text length of research articles is limited to 8000 words, excluding figures, tables and references. All text should be written in a concise way, by focusing on major points, findings, breakthrough or discoveries, and their broad significance. All running text should be in Times 11 or Times New Roman 11, with 1.5 line spacing. Figure and table captions must be self-explanatory and they should be written in Times 10 or Times New Roman 10. Lines, as well as every page of the manuscript, including the title page, references, tables, etc. should be numbered.

Title

The title of research articles should be concise and informative and focused on the main scientific discovery. Authors are advised to look at examples in recent issues of the journal.

Abstract

The research articles abstract of less than 300 words should report concisely on the main scientific breakthrough. The abstract should not contain **abbreviations** nor **literature references**. The abstract is structured in three parts: the first part summarizes the Introduction section, it thus gives the background, the overall and specific issues, and the hypothesis (about 3-4 sentences). The second part abstracts the Experimental section, it thus gives a brief overview of the experiments or surveys (about 2-3 sentences). The third part abstracts the Results and discussion section, it thus gives: the 1-2 major results using precise trends and data, then the interpretation of those results, then the claimed novelty of those results versus current knowledge, then the basic or applied benefits of those results for sustainable agriculture. Novelty claims should be made in an **affirmative way**, using for instance “Here we show that ...”, “Here we demonstrate that ...” or “This is the first...”

Abbreviations

In general abbreviations should be avoided in the main text because they decrease article readability and impact. Only 1-2 common abbreviations such as DNA or LED are accepted in the main text. When their use is essential, abbreviations must be explained when they first appear in the text.

Abbreviations in figures, tables and equations are accepted only if there is not enough space to write full words. Here, abbreviations should be explained in figure and table captions, or after equations.

Footnotes

Footnotes in the running text and in tables are not accepted. Table footnotes should be included in the table caption.

Units

Data description in the text, tables and figures should follow the International System of Units, as it is the most widely used system of measurement. The choice of another system of units may be tolerated if it is explained and argued clearly.

6. REQUIRED FORMAT **FOR REVIEW ARTICLES**

For review articles please follow the **general instructions for research articles**, with the following exceptions:

- The text length of review articles is limited to **16000 words**, excluding figures, tables and references.
- The title should end by ". A review"
- The abstract of less than 300 words **should contain two parts**: the first part should give general and

  global issues, then specific and scientific issues in about 5-6 sentences. The second part should start by, e.g., "Here we review...", and explain the interest of the review. Then the major advances demonstrated in the article by literature analysis should be presented: "The major points are the following: 1)... 2)...". The reader should clearly understand the added value of those advances.

- The first section of the article should be "1. Introduction", and the last section "X. Conclusion", and sections should have topics titles. The structure should not be of IMRaD type (Intro Methods Results and Discussion). All sections and sub-sections **should be numbered**. At the end of each section, authors are advised to propose a concise view of the novelty described and/or the main research hypotheses addressed by the reviewed knowledge.
- A **Contents** should be inserted after the list of keywords, before the introduction section.

7. REQUIRED FORMAT FOR META-ANALYSES

For meta-analyses, please follow the general instructions for research articles, with the following exceptions:

- The title should end by ". A meta-analysis"
- An additional section "**References of the meta-analysis**" should be inserted after the "References"

  section
  Meta-analyses should meet the following criteria[1]:

- The **procedure** used to select papers from scientific databases should be **explained**,
- Individual data should be **weighted** according to their level of precision when possible,
- **Site-year variability** of the results should be analyzed from an agronomic point of view, to identify relevant explanatory variables,
- Efforts should be made to check for the **publication bias** and **confounding effects**. **8. REFERENCES**

Citation

Cite references in the text by name and year in parentheses. Some examples:

- Negotiation research spans many disciplines (Thompson 1990).
- This result was later contradicted by Becker and Seligman (1996).
- This effect has been widely studied (Abbott 1991; Barakat et al. 1995; Kelso and Smith 1998;

  Medvec et al. 1993).

Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text. Do not use footnotes or endnotes as a substitute for a reference list. Reference list entries should be alphabetized by the last names of the first author of each work. The DOI should be indicated when available.

Journal article

Eden M, Gerke HH, Houot S (2017) Organic waste recycling in agriculture and related effects on soil water retention and plant available water: a review. Agron Sustain Dev 37 (2):21. doi:10.1007/s13593- 017-0419-9

Lamichhane JR, Durr C, Schwanck AA et al. (2017) Integrated management of damping-off diseases. A review. Agron Sustain Dev 37 (2):25. doi:10.1007/s13593-017-0417-y

[1] Philibert A, Loyce C, Makowski D.(2012) Assessment of the quality of meta-analysis in agronomy. Agriculture, Ecosystems & Environment, 148, 72-82. DOI: 10.1016/j.agee.2011.12.003.

Ideally, the names of all authors should be provided, but the usage of “et al” in long author lists will also be accepted:

Article by DOI
Coqueret V, Le Bot J, Larbat R et al. (2017). Nitrogen nutrition of tomato plant alters leafminer

dietary intake dynamics. J Insect Physiol. doi:10.1016/j.jinsphys.2017.04.002

Book
Mengel K, Kirkby EA (1987) Principles of plant nutrition. International Potash Institute, Bern
Book chapter

García-Tejero I.F., Durán-Zuazo V.H., Muriel-Fernández J.L. et al. (2011) Water and Sustainable Agriculture. In: Water and Sustainable Agriculture. SpringerBriefs in Agriculture. Springer, Dordrecht, pp. 1-94 **Online document** Cartwright J (2007) Big stars have weather too. IOP Publishing PhysicsWeb.
http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007
Dissertation
Alloush GA (1990) The mechanism of mobilization of iron from soil minerals in the rhizosphere of Cicer arietinum L. Dissertation, University of Leeds

Always use the standard abbreviation of a journal's name according to the ISSN List of Title Word Abbreviations, see http://www.issn.org/services/online-services/access-to-the-ltwa/

For authors using EndNote, an output style that supports the formatting of in-text citations and reference list is available at: http://endnote.com/downloads/style/agronomy-sustainable-development. For authors using

Mendeley or Zotero, the style you can download the CSL file for this journal.
The authors should check very carefully that references cited in the text are in match with the reference list; and that all references in the list are really cited in the text. The accuracy of references should also be carefully checked.

9. ARTWORK (TABLES AND FIGURES)

Color figure in the introduction section

For all the article types, the introduction must contain 1-2 color photos (named Figure 1). The photo(s) should reveal the main topic of the article to a wide audience.

Number of tables and figures

For research articles, the number of tables plus figures is limited to 8, including the introduction color figure. Figures should be preferred to tables. For review articles and meta-analyses, there is no limitation of tables/figures number.

Colors

Color illustrations are accepted at no charge both for the electronic version and the printed version of the journal.

Format

The titles of figure and axes should be bold.
The **Y-axis title should be written horizontally** at the above-left of the graph, when possible.
Preferably, a graph should contain a maximum of 3 curves.
Symbol legends are not accepted; the name of a curve should be written in the graph, beside the corresponding curve, using arrows if necessary.

Regression equations should not appear on the graph, but rather at the end of the caption
A figure should not contain too many sub-items, in order to be readable. Sub-items should not have any frame.
Tables should have a reasonable size. Tables longer than 1 page are not recommended.

WRONG RIGHT

Authors are encouraged to use contrasting colors (red, blue, green...) to increase the readability of the figures.
Do not use faint lines and/or lettering and check that all lines and lettering within the figures are legible at final size.
Do not use background lines
All lines should be at least 1 pt wide
Do not repeat the curve names in the different sub-figures.

Lettering

- To add lettering, it is best to use Helvetica or Arial (sans serif fonts).
- Keep lettering consistently sized throughout your final-sized artwork, usually about 2–3 mm (8–12

  pt).

- Variance of type size within an illustration should be minimal, e.g., do not use 8-pt type on an axis

  and 20-pt type for the axis label.

- Avoid effects such as shading, outline letters, etc.
- Do not include titles or captions within your illustrations.

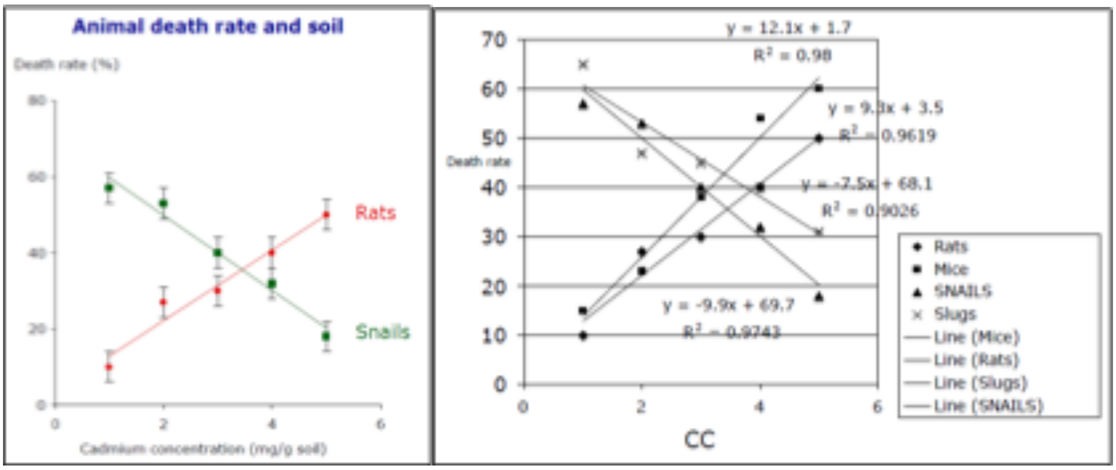
Numbering

- All figures are to be numbered using Arabic numerals.
- Figures should always be cited in text in consecutive numerical order.
- Figure parts should be perfectly aligned, have the same size and denoted by lowercase letters (a, b,

  c, etc.). The placement of letters in the figure parts should be consistent throughout the paper (i.e. preferably top left)..

Captions

A "scheme" or "photo" should be named "figure". Figure captions should be self-explanatory and must contain a brief description of the main scientific point of the figure, using 1–2 well thought sentences: a



8

figure should be almost understandable without reading the main body text of the article. The characters should be in Times or Times New Roman with an appropriate size to be readable after 50% reduction.
Do not refer to colors in the captions in case readers print in black and white

Resolution and quality

Figures and tables should be of high quality.

- Scanned line drawings and line drawings in bitmap format should have a minimum resolution of 1200 dpi.
- Combination artwork should have a minimum resolution of 600 dpi
- Halftones should have a minimum resolution of 300 dpi

Figure Placement and Size

 Tables and figures should be uploaded as separated files at the submission stage. Their place in the manuscript should be clearly indicated by authors.

- When preparing your figures, size figures to fit in the column width.
- The figures should be 39 mm, 84 mm, 129 mm, or 174 mm wide and not higher than 234 mm.

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If you include figures that have already been published elsewhere, you must obtain permission from the copyright owner(s) for both the print and online format. Please be aware that some publishers do not grant electronic rights for free and that Springer will not be able to refund any costs that may have occurred to receive these permissions. In such cases, material from other sources should be used.

Accessibility

In order to give people of all abilities and disabilities access to the content of your figures, please make sure that

- All figures have descriptive captions (blind users could then use a text-to-speech software or a text-to-Braille hardware)
- Patterns are used instead of or in addition to colors for conveying information (color-blind users would then be able to distinguish the visual elements)
- Any figure lettering has a contrast ratio of at least 4.5:1

10. ELECTRONIC SUPPLEMENTARY MATERIAL

The need for supplementary material section must be justified in the cover letter.
Data should be rather deposited in repositories than submitted as supplementary materials.

Submission

- Supply all supplementary material in standard file formats.
- Please include in each file the following information: article title, journal name, author names; affiliation and e-mail address of the corresponding author.

To accommodate user downloads, please keep in mind that larger-sized files may require very long download times and that some users may experience other problems during downloading.

Collecting Multiple Files

It is possible to collect multiple files in a .zip or .gz file.

Captions

For each supplementary material, please supply a concise caption describing the content of the file.

Processing of supplementary files

Electronic supplementary material will be published as received from the author without any conversion, editing, or reformatting.

Accessibility

In order to give people of all abilities and disabilities access to the content of your supplementary files, please make sure that

- The manuscript contains a descriptive caption for each supplementary material
- Video files do not contain anything that flashes more than three times per second (so that users prone to seizures caused by such effects are not put at risk)

11. DECLARATIONS

All authors are requested to include information regarding sources of funding, financial or non-financial interests, study-specific approval by the appropriate ethics committee for research involving humans and/or animals, informed consent if the research involved human participants, and a statement on welfare of animals if the research involved animals (as appropriate).

If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section.

The Editors reserve the right to reject manuscripts that do not comply with the guidelines. The author will be held responsible for false statements or failure to fulfill the guidelines.

11.1. Funding and conflicts of interest

Authors are requested to disclose interests that are directly or indirectly related to the work submitted for publication. Interests within the last 3 years of beginning the work (conducting the research and preparing the work for submission) should be reported. Interests outside the 3-year time frame must be disclosed if they could reasonably be perceived as influencing the submitted work. Disclosure of interests provides a complete and transparent process and helps readers form their own judgments of potential bias. This is not meant to imply that a financial relationship with an organization that sponsored the research or compensation received for consultancy work is inappropriate.

Interests that should be considered and disclosed but are not limited to the following:

Funding: Research grants from funding agencies (please give the research funder and the grant number) and/or research support (including salaries, equipment, supplies, reimbursement for attending symposia, and other expenses) by organizations that may gain or lose financially through publication of this manuscript.

Employment: Recent (while engaged in the research project), present or anticipated employment by any organization that may gain or lose financially through publication of this manuscript. This includes multiple affiliations (if applicable).

Financial interests: Stocks or shares in companies (including holdings of spouse and/or children) that may gain or lose financially through publication of this manuscript; consultation fees or other forms of remuneration from organizations that may gain or lose financially; patents or patent applications whose value may be affected by publication of this manuscript.

It is difficult to specify a threshold at which a financial interest becomes significant, any such figure is necessarily arbitrary, so one possible practical guideline is the following: "Any undeclared financial interest that could embarrass the author were it to become publicly known after the work was published."

Non-financial interests: In addition, authors are requested to disclose interests that go beyond financial interests that could impart bias on the work submitted for publication such as professional interests, personal relationships or personal beliefs (amongst others). Examples include, but are not limited to: position on editorial board, advisory board or board of directors or other type of management relationships; writing and/or consulting for educational purposes; expert witness; mentoring relations; and so forth.

Primary research articles require a disclosure statement. Review articles present an expert synthesis of evidence and may be treated as an authoritative work on a subject. Review articles therefore require a disclosure statement.

Please note that, in addition to the above requirements, funding information (given that funding is a potential conflict of interest (as mentioned above)) needs to be disclosed upon submission of the manuscript in the peer review system. This information will automatically be added to the Record of CrossMark, however it is not added to the manuscript itself. Under 'summary of requirements' (see below) funding information should be included in the 'Declarations' section.

Summary of requirements

The above should be summarized in a statement and placed in a ‘Declarations’ section before the reference list under a heading of ‘Funding’ and/or ‘Conflicts of interests’/’Competing interests’.

Please see the various examples of wording below and revise/customize the sample statements according to your own needs.

When all authors have the same (or no) conflicts and/or funding it is sufficient to use one blanket statement. Examples of statements to be used when funding has been received:

- Partial financial support was received from [...]
- The research leading to these results received funding from [...] under Grant Agreement No[...].
- This study was funded by [...]
- This work was supported by [...] (Grant numbers [...] and [...]

  Examples of statements to be used when there is no funding:

- The authors did not receive support from any organization for the submitted work.
- No funding was received to assist with the preparation of this manuscript.
- No funding was received for conducting this study.
- No funds, grants, or other support was received.

Examples of statements to be used when there are interests to declare:

- **Financial interests:** Author A has received research support from Company A. Author B has received a speaker honorarium from Company Wand owns stock in Company X. Author C is consultant to company Y.

  Non-financial interests: Author C is an unpaid member of committee Z.

- **Financial interests:** The authors declare they have no financial interests.

  Non-financial interests: Author A is on the board of directors of Y and receives no compensation as member of the board of directors.

- **Financial interests:** Author A received a speaking fee from Y for Z. Author B receives a salary from association X. X where s/he is the Executive Director.

  Non-financial interests: none.

- **Financial interests:** Author A and B declare they have no financial interests. Author C has received speaker and consultant honoraria from Company M and Company N. Dr. C has received speaker honorarium and research funding from Company M and Company O. Author D has received travel support from Company O.

  Non-financial interests: Author D has served on advisory boards for Company M, Company N and Company O.

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- The authors have no conflicts of interest to declare that are relevant to the content of this article.
- All authors certify that they have no affiliations with or involvement in any organization or entity

  with any financial interest or non-financial interest in the subject matter or materials discussed in

  this manuscript.

- The authors have no financial or proprietary interests in any material discussed in this article.

11.2. Ethics approval

When reporting a study that involved human participants, their data or biological material, authors should include a statement that confirms that the study was approved (or granted exemption) by the appropriate institutional and/or national research ethics committee (including the name of the ethics committee) and certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. If doubt exists whether the research was conducted in accordance with the 1964 Helsinki Declaration or comparable standards, the authors must explain the reasons for their approach, and demonstrate that an independent ethics committee or institutional review board explicitly approved the doubtful aspects of the study. If a study was granted exemption from requiring ethics approval, this should also be detailed in the manuscript (including the reasons for the exemption).

11.3. Consent to participate

For all research involving human subjects, freely-given, informed consent to participate in the study must be obtained from participants (or their parent or legal guardian in the case of children under 16) and a statement to this effect should appear in the manuscript.

For manuscripts reporting studies involving vulnerable groups where there is the potential for coercion or where consent may not have been fully informed, extra care will be taken by the editor and may be referred to the Springer Nature Research Integrity Group.

Examples of statements:

- Informed consent was obtained from all individual participants included in the study.
- Verbal informed consent was obtained prior to the interview.

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Individuals may consent to participate in a study, but object to having their data published in a journal article. Authors should make sure to also seek consent from individuals to publish their data prior to submitting their paper to a journal. This is in particular applicable to case studies.

Examples of statements :

The authors affirm that human research participants provided informed consent for publication of the images in Figure(s) 1a, 1b and 1c.

11.5. Data availability statement - Code availability statement

The journal **encourages authors to provide a statement of data availability** in their article. Data availability statements should include information on where data supporting the results reported in the article can be found, including, where applicable, hyperlinks to publicly archived datasets analyzed or generated during the study. Data availability statements can also indicate whether data are available on request from the authors and where no data are available, if appropriate.

Data Availability statements can take one of the following forms (or a combination of more than one if required for multiple datasets):

1. The datasets generated during and/or analyzed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS]

2. The datasets generated during and/or analyzed during the current study are not publicly available due [REASON WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.

3. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

4. Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

5. All data generated or analyzed during this study are included in this published article.

13

Please see Springer Nature's website for detailed information about

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-examples of data availability statements (http://www.springernature.com/gp/authors/research-data- policy/data-availability-statements)

11.6. Authors contribution

Please provide your and your co-authors' contribution to the research, according to the CRediT taxonomy[2] defined in the table below. Please use initials to refer to each author's contribution.

Examples:

- " Conceptualization, S.C.P. and S.Y.W.; Methodology, A.B., S.C.P. and S.Y.W.; Investigation, M.E., A.N.V., N.A.V., S.C.P. and S.Y.W.; Writing – Original Draft, S.C.P. and S.Y.W.; Writing – Review & Editing, S.C.P. and S.Y.W.; Funding Acquisition, S.C.P. and S.Y.W.; Resources, M.E.V and C.K.B.; Supervision, A.B., N.L.W., and A.A.D"
- "All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [full name], [full name] and [full name]. The first

draft of the manuscript was written by [full name] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript."

For review articles where discrete statements are less applicable a statement should be included who had the idea for the article, who performed the literature search and data analysis, and who drafted and/or critically revised the work.

For articles that are based primarily on the student's dissertation or thesis, it is recommended that the student is usually listed as principal author:

A Graduate Student's Guide to Determining Authorship Credit and Authorship Order, APA Science Student Council 2006

CONTRIBUTOR ROLE	ROLE DEFINITION
Conceptualization	Ideas; formulation or evolution of overarching research goals and aims.
Methodology	Development or design of methodology; creation of models
Software	Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components.
Validation	Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of results/experiments and other research outputs.
Formal analysis	Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data.
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection.
Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools.
Data Curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse.
Writing – original draft preparation	Creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation).
Writing – review and editing	Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre- or post-publication stages.
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Project administration	Management and coordination responsibility for the research activity planning and execution.
Funding acquisition	Acquisition of the financial support for the project leading to this publication.

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- This journal is committed to upholding the integrity of the scientific record. As a member of the Committee on Publication Ethics (COPE) the journal will follow the COPE guidelines on how to deal with potential acts of misconduct.
- Authors should refrain from misrepresenting research results which could damage the trust in the journal, the professionalism of scientific authorship, and ultimately the entire scientific endeavour. Maintaining integrity of the research and its presentation is helped by following the rules of good scientific practice, which include*:
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- The submitted work should be original and should not have been published elsewhere in any form or

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- A single study should not be split up into several parts to increase the quantity of submissions and submitted to various journals or to one journal over time (i.e. 'salami-slicing/publishing').
- Concurrent or secondary publication is sometimes justifiable, provided certain conditions are met. Examples include: translations or a manuscript that is intended for a different group of readers.
- Results should be presented clearly, honestly, and without fabrication, falsification or inappropriate data manipulation (including image based manipulation). Authors should adhere to discipline- specific rules for acquiring, selecting and processing data.
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Important note: the journal uses a software to screen for plagiarism.

- Authors should make sure they have permissions for the use of software, questionnaires/(web) surveys and scales in their studies (if appropriate).
- Research articles and non-research articles (e.g. Opinion, Review, and Commentary articles) must cite appropriate and relevant literature in support of the claims made. Excessive and inappropriate self-citation or coordinated efforts among several authors to collectively self-cite is strongly discouraged.

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• Authors are strongly advised to ensure the author group, the Corresponding Author, and the order of authors are all correct at submission. Adding and/or deleting authors during the revision stages is generally not permitted, but in some cases may be warranted. Reasons for changes in authorship should be explained in detail. Please note that changes to authorship cannot be made after acceptance of a manuscript.

*All of the above are guidelines and authors need to make sure to respect third parties rights such as copyright and/or moral rights.

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Contents

Data Sharing Policy

Publication Charges

Copyright Options

Complying with Funding Agencies

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Fernanda Gomes Moojen was born on March 11, 1991, in Santa Maria, Rio Grande do Sul state, Brazil, daughter of Eduardo Londero Moojen (*in memoriam*) and Juliana Brugine Gomes. In her childhood, she had her first contact with the scientific world when she accompanied her parents at the Federal University of Santa Maria. She attended elementary school in her hometown and high school in Tupanciretã. In 2009, Fernanda started college in Agronomy at the Universidade Federal do Rio Grande do Sul (UFRGS). As scientific initiation, Fernanda started working one semester in a Soil Science Laboratory and one semester in the Grazing Ecology Research Group (GPEP). Then, she spent four years at the Study Group on Beef Cattle Production Systems and Production Chain (NESPro) under the supervision of Dr. Júlio Barcellos. During her undergraduate career, she received three awards: Highlight Animal Production - Ruminants at the XXII UFRGS Scientific Initiation Meeting, Highlight Agrarian Sciences at the IX UFRGS Teaching Salon, and the UFRGS Innovative Talent Award at the UFRGS Technological Innovation Fair - FINOVA. She did an academic exchange in 2012 at the Universidad Nacional de Asunción in Paraguay that provided her first international contacts. The following year she did internships on ten farms in New Zealand. In addition to small internships in Rio Grande do Sul and Argentina, Fernanda completed her final college stage at GAPPI - a consulting enterprise in irrigated or fertigation in animal production systems in Mato Grosso and Minas Gerais. Fernanda graduated as an agronomy engineer in December 2014. Soon, in January 2015, she spent a month with Dr. Anibal de Moraes, who were caring projects in forage science at The Ohio State University. In March 2015, Fernanda re-joined the GPEP to work on her master´s course at the Animal Science Research Program – UFRGS, under the coordination of Carolina Bremm. She conducted a long-term experimental protocol in integrated crop-livestock systems (ICLS) in lowlands with the group. She worked on the database of another long-term protocol of ICLS that was the theme of her dissertation. In 2017, Fernanda started her Ph.D. under Dr. Paulo Cesar de Faccio Carvalho´s coordination, working on ICLS design. She participated in developing the Farm Coaching initiative in partnership with SIA- Serviço de Inteligência em Agronegócios. During her Ph.D., she spent one year at the Institut National de Recherche pour l'agriculture, l'alimentation et l'environnement (INRAE) – Toulouse/France, developing her work in co-design of ICLS with Dr. Julie Ryschawy.