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Commission on Sustainable Agriculture Intensification

Investigating pathways for agricultural innovation at scale: Case studies from Brazil

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Executive summary

CoSAI Innovation Pathways Study: Brazil country study

This is one of three country studies on Innovation Pathways in Agri-food Systems, managed by the Commission for Sustainable Agriculture Intensification (CoSAI).[1] The three studies use a common analytical framework to generate lessons on factors leading to successful innovation pathways, to guide future investment.

Sustainable food systems in Brazil: Challenges and opportunities for innovation

Brazil is one of the main producers and exporters of food in the world, including grains, meats and many other products (Aragão and Contini 2021). Despite the significant improvements in productivity, led by technological adoption and spread, there are still the challenges of reducing inequalities and the impacts of food systems on climate change and biodiversity. Given its size, Brazil plays an important role in the search for more sustainable ways to produce food, since both the most advanced technologies for intensive agricultural production and subsistence farming systems coexist in the country. There is also a wide range of experiences in terms of agri-food production systems and public policies for applying these systems, as well as private-sector initiatives that meet the challenge of sustainable intensification (Antoniazzi et al. 2013). This study summarizes the development and scaling up processes of four initiatives in Brazil that are aligned with the transformative changes needed in agricultural systems to address these complex challenges.

The cases were selected using the following criteria: (1) successful innovation at scale; (2) implemented in the last two decades; (3) transformative in environmental, social or economic aspects of the food system; (4) representative of a variety of innovators and types of innovations. The case study methodology sought to show how and why the innovation was developed and scaled. A document review was carried out from publicly available sources and supplemented with interviews with key actors in the development of the innovation. The goal was to produce practical, evidence-based lessons on pathways for innovation in SAI. The four Brazilian cases are summarized below.

1. Balde Cheio (the Full Bucket Project) is a successful case of technology transfer with a joint learning approach involving farmers, extension agents and researchers from Embrapa (the Brazilian Agricultural Research Corporation). Balde Cheio started in 1998, led by Artur Chinelato and André Novo (Southeast Livestock Division of Embrapa). The project is an effective response to the complexity of dairy farming – given the multiple interactions of soil, plant, climate, herd, work and farm management – and the different farmer profiles (though mainly family farmers) and varying production conditions; it delivers significant results in sustainable intensification. The project consists of the comprehensive, integrated and long-term training of technician and extension agents to provide high-quality, continuous and farmer-oriented extension services, bridging the gap between research and end users (Novo et al. 2014). Using a local small farm as a classroom, its practical approach combines the use of experiments and social learning in a 4-year process of sequential and incremental

[1] All of the studies are available on the CoSAI website (https://wle.cgiar.org/cosai/pathways-for-innovation).

technology introduction. The most significant impacts reported include a three-fold increase in productivity and income generation, job creation, soil and water conservation, improvement in milk quality, food safety, animal health and wellbeing (Novo et al. 2013; Malagutti et al. 2021). Over more than two decades, Balde Cheio expanded organically, through regional and local partnerships, to around 500 municipalities in all regions of the country, driven by local and regional demand (Novo 2021; Malagutti 2020).

2. One Land and Two Waters Program (P1+2) it is an outstanding example of fast scaling up of an innovation package through a mission-oriented policy implemented in partnership with civil society networks. The program aims to improve access to water for producing healthy foods and guaranteeing food and nutritional security for the poor in the semiarid region of Brazil. The innovation involves a set of social technologies to harvest and store water (mainly cisterns and small dams) developed to strengthen the ability to live in the semiarid region, implemented through an institutional arrangement involving the government and civil society. From 2007 to 2020, P1+2 increased access to water for more than socially vulnerable 200,000 families in the semiarid region (Ministério da Cidadania 2020). This significantly transformed the beneficiaries' lives by allowing them to expand or start food production, improving the family's nutrition and climate resilience. Women were also empowered in the process, since they are usually in charge of vegetable growing and fetching water. In addition, there was an increase in economic benefits through income generation and savings on food expenses (Pires 2021). The institutional arrangement between the federal government (the main funder), the managing non-governmental organization (NGO) (AP1MC; One Million Cisterns Program Association) and implementing NGOs organized into a network, is one of the innovative factors in the implementation of a public policy that enabled the reach of scale.

3. Integrated production systems (integrated livestock and crops [ILP] and integrated livestock, crops and forest [ILPF]) comprise the use of different production systems (agricultural, livestock and forestry) simultaneously, in succession or in rotation within the same area, for the mutual benefit of all them. Integration increases the complexity of production systems and the results are difficult to measure due to the varied possible combinations and the diverse regional conditions, inputs used and other factors. In general, the results achieved in the farms with ILP and ILPF are: Increased production (crop, livestock, wood and non-wood products) in the same area; optimization and intensification of soil nutrient cycling; increase in biodiversity and agricultural sustainability; increase in farmers' net income due to increased diversification and production; improved animal welfare; improved soil quality and conservation of soil productivity; economic stability with lower risks and uncertainties thanks to production diversification; optimized production processes and factors, and mitigation of greenhouse gas emissions (ILPF Network 2019). Embrapa began research on integrated systems in the 1980s to reduce the recovery costs of degraded pastures in the Cerrado biome. In 2009, due to the environmental benefits of ILP and ILPF systems, integrated systems were chosen as one of the strategies for decarbonizing agriculture in the bundling of provisions for meeting Brazil's voluntary commitment to reduce greenhouse gas emissions for the National Climate Change Policy. In 2010-21, the total area under ILP and ILPF in Brazil increased from 5.5 million hectares (ha) to 17.4 million ha (ILPF Network 2019). The bundling of ILP and ILPF with public policies was the main pathway for the scaling up process.

4. Agrosmart digital monitoring irrigation system (Aqua) was the first product launched by the agtech start-up. The technological innovation offers a decision support platform that provides agronomic insights for the entire agribusiness supply chain with the objective of helping farmers achieve a higher level of water use efficiency, combining the use of sensors, agricultural and meteorological modeling (data science) and a digital platform to deliver the analyzed information as actionable insights for farmers (PIB 2020). The innovators were three graduates, coached by the incubators of public universities and accelerators in the new agtech ecosystem in Brazil. They turned the 2014-16 water crisis in Brazil's southeastern region into an opportunity to innovate, presenting a prototype in start-up contest. After 7 years Agrosmart reached the milestone of 800,000 ha being monitored, attesting to the success of the strategy of developing products for different actors in the value chain. The technological package is more accessible for medium and large farmers, strengthening a trend seen in Brazil that excludes less-capitalized farmers from 4.0 agriculture, as they can only access the technology through an intermediary, such as companies or cooperatives. Recent success stories published by Agrosmart report a 60% reduction in water use and a 30-40% reduction in energy used in the crop irrigation process, in addition to a 20% increase in productivity, reducing costs and risks, all of which align with the context of climate change.

The cases show how the Brazilian innovations have evolved and been adapted to respond to major social, environmental and economic challenges through a systemic/integrative approach that combines consolidated institutions, extension services and end-user participation. The analyses showed that the four cases share three key factors in the innovation and scaling up processes:

a) Innovative technological solutions (even if not new)
b) Partnerships (between beneficiaries and public and private organizations)
c) Leadership (strongly personal at the beginning of the process and in times of crisis). Afterwards, strong institutions are more important to continuity, partnerships and resilience.

Demand already existed for Balde Cheio and P1+2 and therefore gains in scale emerged mainly from the capability to establish a consistent institutional arrangement that ensured its expansion and consistent financing. Second, leaders were important for keeping the organization's mission on course, especially when institutions were new or weakly structured. Third, the technological solution itself needed to be constantly modified, complemented or extended. This is clearly the case for P1+2, which was complementary to a previous project that had robustness the institutional arrangements and leadership already in place.

For ILP and ILPF and the Agrosmart irrigation system, demand needed to be built, so the technological solution was the fundamental element on which leadership had to be based, after which came the partnerships/arrangements for gaining scale. This is the case for most start-ups like Agrosmart, which put an interesting solution on the market, and then seek to gain scale by investing in partnerships and communication. For ILP and ILPF, the technology under development and its improvements were the results of experimental research conducted by Embrapa even before climate change and low carbon technologies came to the fore as one of the biggest problems facing humanity. Consequently, initial demand was slow and had to be disseminated through leaders and institutional arrangements.

It is important to point out that the lessons learned from the case studies are strongly related to Brazil's institutional context, which, despite its weaknesses, is still endowed with functional monitoring and control mechanisms. In this sense, any transfer of the lessons learned to countries with less institutional maturity and organization will need to be adapted to the countries' circumstances, mainly because of the importance of the institutional arrangements for scaling up an innovation for agricultural sustainability.

In addition, when analyzing the processes for sustainable agricultural intensification, other factors unique to Brazil should be considered, such as: (1) a consolidated (internal and external) demand for Brazil's agricultural products and a well-structured processing and supply chain capable of absorbing the results of sustainable intensification; (2) Brazil is one of the main global players in the commodities market, which already positions it as a recipient of substantial public and private investments in the agricultural sector. In other words, any replication of the case studies and the lessons learned must consider the biophysical, economic, social and political dimensions of the country.

Lessons and recommendations

1. **Bundling solutions can improve effectiveness of SAI**

Recommendations

- Mission-oriented policies are essential to provide long-term funding and promote multiple innovations for the same overarching agenda.
- Governments or private funders should clearly identify the big challenges in order to stimulate multiple innovations.

2. **Leadership (personal) is important to guarantee the continuity, maturity and visibility/marketing of innovation**

Recommendations

- The leader should focus on institutional arrangements and the incorporation of innovation into the institutional agenda. It is also important to prepare other people to take on roles within the innovation.
- Map and select local organizations that have a good relationship with local farmers, governments and industries to lead the innovation process.
- Invest in personal capacity building and in programs for training new leaders.

3. **Partnerships are essential for long-term sustainability and scaling up**

Recommendations

- Create a specific governance structure to manage the innovation.
- Include organizations along the value chain, from farmers to the consumer market.

4. **The national and international contexts play a significant role in innovation demand**

Recommendations

- Invest in tools to measure and monitor the innovation results, along with good accountability and traceability systems. These are useful to demonstrate the benefits and generate demand.
- Observe how innovations can match political or economic windows of opportunity.

5. **Continuous and good-quality extension services are essential to any initiative in SAI, especially if it involves small farmers**

Recommendations

- Extension services can be more efficient if structured at the regional scale to meet different regional needs: Financing, management, technical and research.
- Use the training-the-trainer approach for high gains in scale.
- Invest in training platforms, such as distance e-learning courses combined with simple platforms such as WhatsApp to facilitate access for small farmers.
- Consider the extension service as part of the cost of innovation development.

6. **End-user participation is essential for continuous improvement and adjustment**

Recommendations

- Identify organizations with access to farmers (engage and develop learning units).
- Create/establish dialogue channels, participatory and social learning mechanisms (e.g., co-creation laboratories and learning units).
- Support the creation and development of the institutional capacity of farmers' organizations or support innovation mechanisms in existing organizations through organizations that already have knowledge of the local conditions.
- Understand the end-user context to adjust and improve innovations.

1. Introduction

This study is one of three country case studies (the others being India and Kenya) that use a common analytical framework to provide general lessons as well as context-specific findings. The study aims to extract lessons in innovation for SAI, based on concrete examples, to guide future investment by practitioners and investors. The study will also feed into global advocacy by CoSAI and partners to increase and improve the use of funding for research and innovation to rapidly scale up SAI.

According to Commission on Sustainable Agriculture Intensification (CoSAI), innovation for SAI includes not only science and technology but also, importantly, innovation in policies, finance and social institutions. The global demand for sustainable agricultural production is one of the greatest challenges facing humanity today. On the one hand, we have the demand for food to meet the growing population – FAO estimates that a 70% increase in production will be needed to feed 9.1 billion in 2050. And, on the other hand, greenhouse gas emissions must be reduced to net zero by 2050 (FAO 2012).

Brazil is one of the main global producers and exporters of food, including grains, meat and many other products (Aragão and Contini 2021). Despite the significant improvements in productivity, led by widespread technological adoption, there are still the challenges to reduce inequalities and the impacts of food systems on climate change and biodiversity. Given its continental dimension, Brazil plays an important role in the search for more sustainable food production methods, since both the most advanced technologies for intensive agricultural production and subsistence farming systems are found in the country. There is also a wide range of experiences in terms of agri-food production systems and public policies for applying these systems, as well as private-sector initiatives that meet the challenge of sustainable intensification (Antoniazzi et al. 2013). This report summarizes the innovation, development and scaling up processes of four initiatives in Brazil that are at least partly aligned with the transformative changes needed in agricultural systems to address these complex challenges.

Over the past few decades, Brazil has strengthened its public administration, especially at the federal level, through the establishment of monitoring mechanisms and the selection of staff through competitive public examinations. This has had significant effects on the governance of its social and environmental policies. Of particular note are public universities and Embrapa (Brazilian Agricultural Research Corporation), a technological innovation public company focused on generating knowledge and technology for Brazilian agriculture that was founded in the 1970s and is part of MAPA (Ministry of Agriculture, Livestock and Food Supply). The development of agricultural research and technical assistance has also been strengthened. In this context, it is important to emphasize that Brazil has public institutions for technical assistance and rural extension at all federal levels (e.g., states and municipalities) in addition to the private institutions that provide those services.

This document presents the results of analyses of four case studies of innovation for sustainable agricultural intensification in Brazil.

2. Methodological approach

This work adopted an investigative approach to pathways of innovation in SAI, using a common analytical framework developed by CoSAI in the form of guiding questions (Annex 1). The common framework questions enabled us to understand the assumptions on which the experiences were based, and their paths and developments for achieving the results.

The case study methodology adopted seeks to answer questions such as “how?” and “why?”. A very common characteristic of case studies, according to Yin (2004), is that, in general, there are many more variables of interest to researchers than data provided in an objective and impartial way that can be used without bias in the analyses. Likewise, the success of the investigation depends on different sources of evidence, which need to converge to enhance the reliability and validity of the findings by triangulating and connecting information, data and evidence. In this respect, a document review was conducted from publicly available sources and supplemented with materials obtained through interviews (Annex 2). The selection of key actors to be interviewed was based on trying to capture different perspectives related to the development and scaling up of innovation, so the interviewees chosen were: (1) actors who participated in the development of innovations; (2) representatives of partner institutions that were important for scaling up; (3) representatives of end users.

Cases were selected using the following criteria: (1) cases of successful innovation at scale from which lessons can be drawn; (2) time period: Lessons were drawn from as far back as 20 years; (3) scale; (4) transformative and progressing toward at least one key SAI objective; (5) representing a variety of innovators; (6) representing a variety of innovations in policy, social institutions, finance, science and technology; (7) representing a variety of interesting and significant cases across the country (small-scale agriculture, medium to large-scale agriculture, and urban and peri-urban agriculture; and (8) representing important biomes/agroecological zones) (Annex 3). Also, due to the limited time and resources available and the restrictions imposed by the COVID-19 pandemic, data availability and ease of access to main actors and institutions were also considered in the cases selected, which were:

1. Balde Cheio (Full Bucket Project)
2. One Land and Two Waters Program (P1+2)
3. Integrated production systems – integrated livestock and crops (ILP) and integrated livestock, crops and forest (ILPF)
4. Agrosmart: digital irrigation monitoring system – Aqua

3. Case studies

3.1 Balde Cheio

Description

In Brazil, dairy farming is widely practiced in more than a million farms distributed across all biomes (Malagutti et al. 2020), and provides incomes and resilience for a large number of small farmers. However, there is low level of technology adoption and low efficiency and productivity in all regions (Vilela et al. 2016; Malagutti et al. 2021), and most existing government extension agents have a limited background in supporting intensive and sustainable milk production (Malagutti 2020).

Balde Cheio aims to develop and adapt sustainable production processes and administrative tools for small dairy farmers and extension service agents (Novo et al. 2014). The program was created by Embrapa. With 44 units across Brazil, Embrapa[2] is a public technological innovation enterprise focused on generating knowledge and technology for Brazilian agriculture. Embrapa was founded in the 1970s and is part of the Ministry of Agriculture, Livestock and Supply. Balde Cheio began in 1998, and after more than two decades of improvement, its technology transfer methodology is recognized across the country as a reference program for training extension agents for providing technical assistance to production units.

In Brazil, lectures given by researchers in local communities are one of the most common strategies for transferring technology to milk farmers. In one of these lectures[3], given in 1997, Embrapa researcher Artur Chinelato realized the limits of this strategy when a farmer asked who would teach the farmers to use the technologies presented and what the continuity of the proposals presented would be. This led a group of five researchers from Embrapa Sudeste to launch Balde Cheio, as a practical teaching method, using a dairy farm as a classroom for technicians and farmers. The initial syllabus consisted of a set of technological practices, tested on experimental farms belonging to educational and research institutions, that could be adapted to different situations, locations and farmer profiles (Novo et al. 2016; Chinelato 2018).

The project began on 12 farms in the states of São Paulo and Minas Gerais. Embrapa researchers used regular visits to train extension workers and farmers working with them on the farms. The first activity was a lecture organized in partnership with Integral Technical Assistance Coordination (CATI), a state institution in São Paulo for training technicians and farmers. After 3 years, an internal evaluation of the project (Novo et al. 2014) indicated significant impacts in terms of productivity and other economic indicators, as well as the improvement of the self-esteem of farmers and extension agents. Another important learning experience was reflecting on how and when a specific technology should be established in practice in a given real-life situation (Aragão and Contini 2021). In the evaluation of this first phase, two elements guided the improvement of the methodology: (1) the strategies had to be customized for each dairy farm, given the complexity of the activity and the wide range of technological possibilities, requiring great skill from researchers and technicians; (2) there was a need

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[2] www.embrapa.br

[3] The lecture was given on September 18, 1997 in Quatis, Rio de Janeiro.

to give the local technicians and the extension agents a greater role in decision-making and manipulating data and indicators.

From that point onwards, the Balde Cheio leaders redirected the project's focus to training extension agents, which continues today. This change worked better with the growing demand for the project and was a better fit for the understanding that it was not Embrapa's role to provide technical assistance to farmers. It became a turning point for the scaling up process, due to the multiplier effect.

The program is a successful case of a method of technology transfer with a joint learning approach, whose core innovations are: (1) technology transfer in an applied manner, in an accessible language for farmers (Novo 2021); (2) high-quality training of extension agents (Novo 2021); and (3) organizing knowledge for managing appropriate technologies for each case (individualized for each farmer rather than being a package). Other Balde Cheio characteristics are its network for exchanging information and practices (Novo et al. 2014); data collection (including baseline data) and monitoring to support technical decisions; an experimental approach, with a constant search for innovation by recombining technologies such as pasture irrigation, intensive pasture stewardship, soil fertility recovery, reproduction efficiency, animal health, environmental preservation, animal husbandry activities, and economic management.

The training program for technicians lasts at least 4 years. The focus is on experimenting with a set of technologies and processes that have already been tested in experimental farms of research institutes and universities but that have not yet been widely adopted due to lack of knowledge and proper extension services. The most commonly used technologies are (Novo et al. 2013): Intensive management of tropical pastures; use of sugarcane and urea in the dry season; simple administrative tools; pasture irrigation and oat/ryegrass overseeding; gradual introduction of specialized genetics; use of by-products in the diet; vaccination schedules; disposal of sick/unproductive animals, changes in herd structure; recovery of riparian forests; improvement of animal welfare.

According to Novo et al. (2004), technology should be introduced at the farmers' pace, so that when and how new technologies and practices are introduced are as important as the investment capital. The experimental approach, using small trials, avoids the risks of misguided expensive investments in technology. For example, "artificial insemination, a symbol of modern dairy farming, is almost never recommended until good reproduction indices have been achieved and a reliable process of rearing calves is in place" (Novo et al. 2014). The program considers there are preconditions that dictate the best sequence for the introduction of technology. To better communicate this process they developed the "gearbox" model (Figure 1). Another aspect of the gearbox model is the interaction between farmers' knowledge and "formal" knowledge, which is very different from the conventional top-down approach.

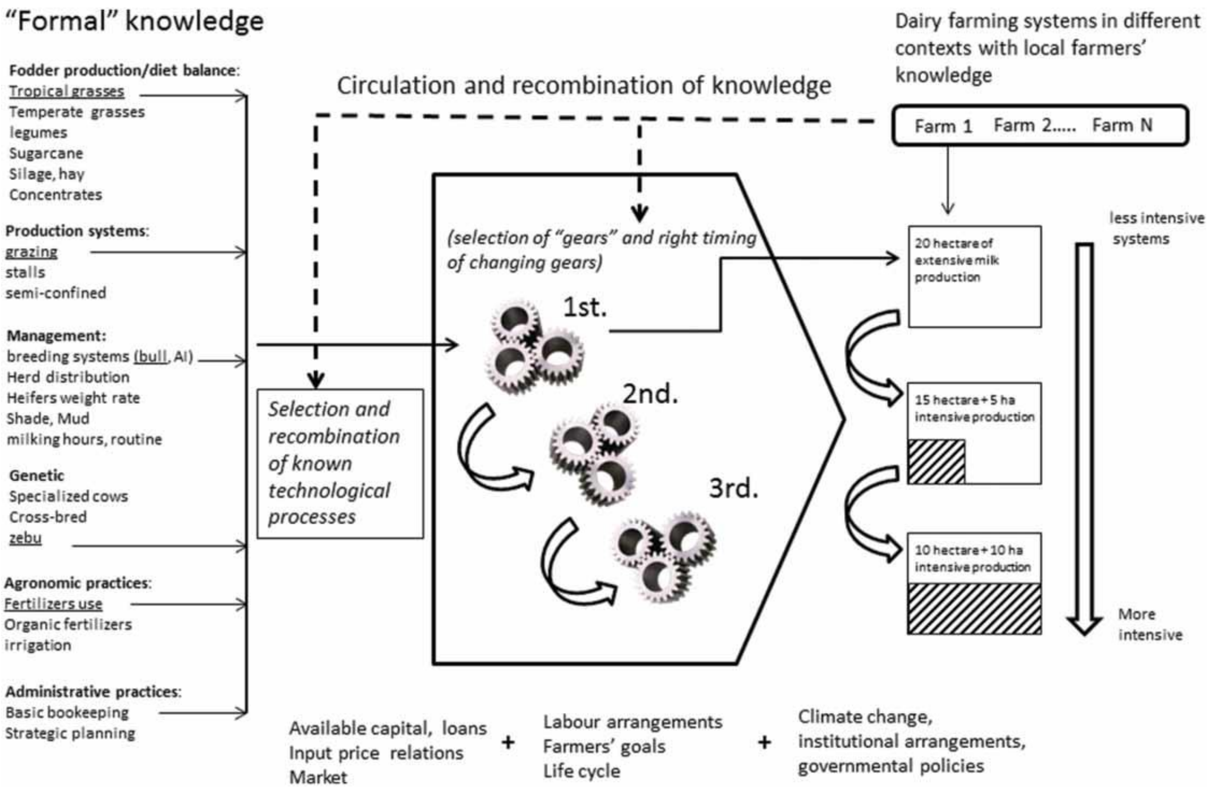

Figure 1. Balde Cheio "gearbox" model: Sequential and incremental technology introduction.

Source: Novo et al. (2014).

The program works as follows (SEBRAE 2019). The extension agents trained by the Embrapa team selects one property per municipality, in agreement with the farmer, to serve as a reference and a classroom, a demonstration unit for other farmers (assisted units) in that region. Producers who wish to participate in the project need to approach program technicians. After the demonstration unit has been selected and approved by the project team, the owner must respond to a questionnaire to identify their production system, aspects related to the family's socioeconomic situation, and issues related to the environment.

- The program also includes theory classes both for extension agents and farmers at the Southeast Livestock Division of Embrapa and on selected farms.
- The demonstration units should preferably have the following characteristics: The farm must be small (0.5 hectare (ha) and preferably less than 10 ha), a family farm (so that there is no interference in teaching the people involved), and the main source of income must be dairy farming.
- The demonstration units receive the following services and materials: Spreadsheets for economic and animal management; soil analysis; sanitary control related to brucellosis and tuberculosis; a detailed geophysical survey of the terrain; identification of animals with ear and other tags.
- Demonstration unit farmers will be assisted by the program's technicians, provided they fulfill the following obligations: Perform tests for detecting brucellosis and tuberculosis, cull animals that test positive; allow their property to be visited by other farmers and other technicians;

always do what has been agreed between those involved; keep records relating to climate, finance and livestock.

- After structuring the property based on the project's guidelines, the demonstration unit becomes a regional reference.
- Together, farmers and technicians set up the appropriate project at their properties and usually receive monthly visits from technicians for follow-up.
- An accredited instructor visits the demonstration unit every 4 months for the duration of the program (4 years), making a total of 12 follow-up visits.

One of the main tools for monitoring, evaluating and planning the intensification process is bookkeeping. The program has simple spreadsheets for farmers to collect their technical and economic data. This provides a realistic view of short- and long-term economic stability, gives the feedback that is necessary for the gearbox model to work, and supports decisions with facts and data, minimizing the risks to the livelihood of farmers (since they are the ones investing). Bookkeeping is required for participation in the program, as coordinators consider that improving dairy production requires closer monitoring. Participants (farmers and technicians) who do not take the task seriously are excluded from the program (Novo 2021).

In 2020, Balde Cheio covered a total of 1,626 farms (326 demonstration units and 1,283 assisted units) in 476 Brazilian municipalities and 21 states. A total of 246 technicians were trained. Although there are no data about the farmers' profiles, most of them are known to be small farmers. Half of the participants are from Minas Gerais state, and in 2017, 72% of farmers covered by the program had less than 280 ha (Barioni Junior 2019).

One of Balde Cheio's main strategies to ensure dissemination and sustainability is to establish partnerships with different types of public institutions (technical assistance and rural extension agencies, linked to state and municipal agriculture secretariats, teaching and research institutions, etc.). Balde Cheio also partners with private institutions (cooperatives, dairy product companies, associations, agricultural federations, the Brazilian Micro and Small Business Support Service (SEBRAE), self-employed professionals, etc.). The majority of partnerships have no formal contract with Embrapa, since there is no flow of financial resources among institutions, each one using their own financial resources.

It is important to highlight the role of partnerships for the program's financial sustainability as well. The so-called "S system"[4] organizations – official or private rural extension agencies, cooperatives, rural unions, NGOs and other partners (Malagutti 2020) (depending on the local arrangement) – employ their own extension agents, and these spend part of their time serving farmers in Balde Cheio. In turn, the instructors are remunerated by farmers, through their representative organization (for example, the National Rural Learning Service [SENAR; Novo 2021], a major partner of the program). The municipality that wants to train its extension agents has to secure the resources to pay the

[4] The S system comprises: National Service for Industrial Learning (SENAI); Social Service for Commerce (Sesc); Industry Social Service (SESI); and the National Service for Commercial Apprenticeship (Senac). Also, part of the S system are: National Rural Learning Service (SENAR); National Cooperative Learning Service (SESCOOP); and Social Transport Service (SEST). (Federal Senate, https://www12.senado.leg.br/noticias/glossario-legislativo/sistema-s)

instructors. Thus, farmers do not make direct payments to the program, although in the future there is a plan to charge better-capitalized farmers. The twice-yearly supervision trips of Embrapa coordinators are funding by Embrapa itself. In the last few years, with limited funds earmarked for research, Embrapa researchers have proposed the creation of a fund for daily and transportation expenses[5], with donations from different sources interested in developing the dairy supply chain.

There is no relationship between farmer profiles and participation in the program. In Balde Cheio, the demonstration units are always small family farms that become practical classrooms, but medium and large farms can also participate as assisted units (Novo 2021). Family farms are chosen as demonstration units because they are more likely to join the program and stay in it: The owners show greater commitment to the activities, since they live on the farm. The importance of women in running the program is also highlighted, as they have ensured successful demonstration units (Novo 2021).

One of the factors that greatly contributed to Balde Cheio reaching scale was creating the role of the instructor in 2004. Instructors were selected for their dedication and commitment to the project's objectives and educator profile. They began training extension agents to provide technical assistance to the farmers across the country. Between 2003 and 2013, the program gained significantly in scale, but in 2013-14 the program suffered some setbacks due to the dissolution of partnerships: Some cooperatives left the program after learning program methodology in order to earn more money by providing technical assistance independently. According to Novo et al (2014), one unforeseen side effect of the program's success has been the appropriation of the Balde Cheio "brand" by others (technical assistance companies, cooperatives and others), raising some issues as interest groups adapt the program to their own needs.

In 2018 Embrapa saw the need to take better ownership of the Balde Cheio brand, paying more attention to partnerships, communication and monitoring, and creating the Balde Cheio em Rede (Full Bucket Network). It expands the program within this institution (currently 14 Embrapa subdivisions, known as units, are involved). The inclusion of new Embrapa units in the network project resulted in the expansion of institutional and operational infrastructure dedicated to the program's actions, with the inclusion of 60 technicians from different Embrapa units, which significantly increased the program's costs.

The Balde Cheio em Rede has four subdivisions (management, training, sustainability and communication) in order to improve external partnership management, consolidate the economic, animal husbandry and technological results in a single database, develop tools for quantifying assisted farms' sustainability, and invest in internal and external communication strategies (Malagutti et al. 2020). Balde Cheio continues to be a long-term program of Embrapa. The restructuring had positive impacts, as indicated by the resumption of the program's expansion from 13 to 21 states (in 2018-20). There was also an increase in the number of technicians in training from 200 to 246, and those in partnerships such as local public extension services, farmers' associations, cooperatives of technicians, dairy industries, NGOs, municipalities, funding agencies (Banco do Brasil Foundation) and development agencies increased from 145 to 182.

[5] Embrapa's annual operating expenses (travel and lodging) for Balde Cheio are BRL 600,000 to BRL 700,000 for 70 people (corresponding to USD 114,595 to USD 133,694).

In 2020, for the first time (due to the pandemic), training carried out online over a longer period (6 months). The online presentation enabled the participation of a greater number of technicians, 104 in all. Previously, some face-to-face trainings had reached similar numbers (80, 90 and even 100), but they were shorter (1 week). Figure 2 shows the increasing scale of the program over the years and the main events that marked its trajectory.

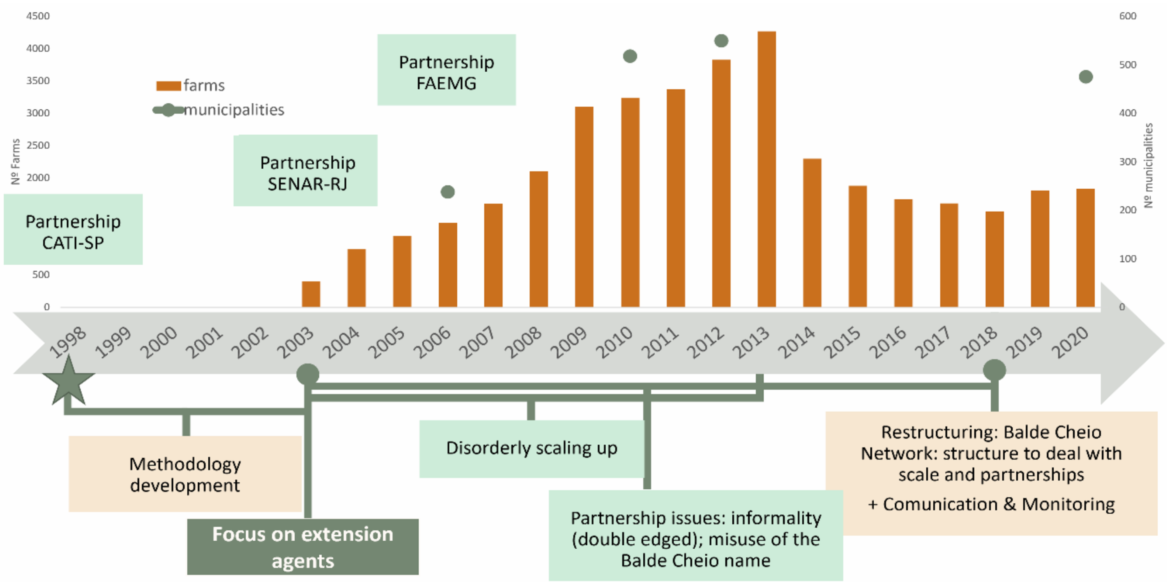

Figure 2. Balde Cheio timeline and number of farmers in the program.

Source: Elaborated by Agroicone, based on Malagutti et al. (2020) and research data.

Actions and actors

Embrapa is responsible for creating and coordinating the project. But it is very important to mention the leadership of Artur Chinelato De Camargo[6], from Embrapa's Southeast Livestock Division, the initiative's creator and main instructor. Currently Chinelato is responsible for the qualification component of the Balde Cheio em Rede. He is frequently mentioned by managers, technicians and farmers as the initiative's major unifying factor, because of his tremendous charisma, passion for the subject, proactivity, easy communication with farmers, great motivational skills, and solid theoretical and practical knowledge.

Embrapa is responsible for training instructors and managing all the partnerships; instructors (well-qualified regional technicians who are responsible for training local technicians); local technicians (extension agents); main partner organizations (which make the connection between the general administration and local partner organizations) and other partner organizations (which enable instructors, mobilize extension agents and farmers, and organize field activities and regional meetings).

[6] All interviewees mention this researcher as the major influence on the program.

As described above, partnerships were essential for the project's dissemination and sustainability. Regional partners usually organize and coordinate the program at a state scale, and in some cases, they finance the instructors and/or Embrapa technicians and their travel expenses. Today, some of the main regional partners[7] link the general administration with local partner organizations. Locally (in municipalities), there are several partner organizations that have their own extension agents. All these partners have a very high demand for well-trained extension agents, so they saw Balde Cheio as a good opportunity.

The demand for the program has been bottom-up (farmers look for extension agents, extension agents look for their respective institutions, institutions look for the project) (Novo 2021). As the program became increasingly well known, demand came from different actors (cooperatives, industries, farmers' associations, farmers, etc.). It is important to note that Brazil has a large number of public and private organizations that offer rural technical assistance (across the country). This is particularly relevant to the project, as these extension agents are trained by Balde Cheio instructors and apply the Balde Cheio methodology, but they are paid by the organizations they are already part of, which does not burden the project itself.

Figure 3 shows the institutional arrangement of the program in the state of Minas Gerais, which is coordinated by regional partner, the Federation of Agriculture of the State of Minas Gerais (FAEMG).

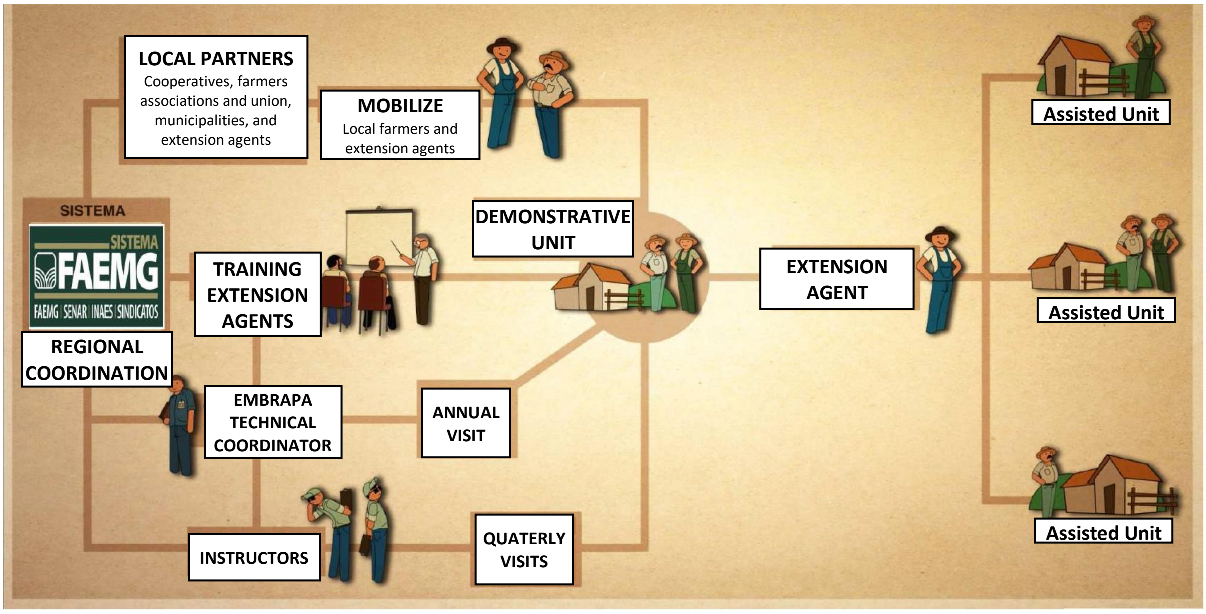

Figure 3. The relationships between Balde Cheio institutions in Minas Gerais.

Source: FAEMG (n.d.).

Finally, it is important to highlight the role of the instructors, people who have a leadership and teaching role. The project currently has 12 instructors who train extension agents across the country.

[7] The main regional partners are: the Federation of Agriculture of the State of Minas Gerais (FAEMG), SENAR, SEBRAE, the Federal Institute of Education of Santa Teresa (Espírito Santo State) and the Sustainable Rural Development Coordination (CDRS-SP).

Innovation is funded by structuring arrangements between regional and local partners (which are different for each location), in which the participation of all those interested in the milk supply chain's technological evolution is fostered. In these arrangements, the local organizations pay for local technical assistance (through availability of its professionals to attend the Balde Cheio training), local expenses and instructors.

The organization's current structure has been shaped progressively, as those interested in developing the supply chain technologically set up arrangements for local implementation. The project's biggest challenges relate to its actors: (1) there is a high turnover of technicians in the program, which puts the continuity of the initiative at risk; (2) although it left an important legacy, the project still relies heavily on its creator (in a personal way) and the possibility of the project weakening without him (Novo 2021).

Outcomes

The most recent evaluation of the program, carried out by Embrapa in 2020 (Malagutti et al. 2020), shows that the most significant impacts include increased productivity and income, job creation, beneficial impacts on environmental conservation (soil and water), improved milk quality, food safety, animal health and wellbeing, and income generation on the farms. Additionally, this type of action can boost local economies by: Stimulating retention of the local population, especially young people, in their original rural space; increasing farmers' and technicians' self-esteem as small dairy farms are often seen as low-income employment with a high level of hardship involved; encouraging the farmers' organizations and public–private partnerships; and expanding movements for stabilizing milk supply, adding value, and verticalization.

Another recent study that applied the multiple correspondence analysis from a multivariate technique evaluated the relationship between economic return and productivity indicators (cattle herd size, production cost, gross income and technical assistance) in 374 livestock farmers from Minas Gerais participating in Balde Cheio. It concluded that the high economic return, in gross margin per hectare, is related to high milk production by cow and a high number of cows per hectare, which are associated with the longer technical assistance to farmers. Although the operational production cost per animal was higher when there was an increase in productivity, the total gross revenue per animal was higher than the cost, resulting in a higher gross margin. Technical assistance for farmers is an important mechanism to increase the productivity of agricultural production.

The entire society benefits indirectly from the production of more food that is also more nutritious and produced to high standards of cleanliness. Processing companies are favored by greater volumes of milk production that are stable throughout the year and meet good quality standards. Municipalities also benefit, as most of the additional income remains in the municipality and moves through local businesses (Malagutti et al. 2020).

As of 2018, with the restructuring of the networked program, there has been greater effort to monitor and systematize the results. However, there are no data to adequately measure the program's reach over its two decades in operation. Several factors make it difficult to measure the results and scale of the program, including: (1) the very nature of the innovation, which can be replicated by other programs and used by trained technicians to serve farmers who are not linked to the program; (2) the participative approach to training activities, opening up and encouraging farmer participation regardless of their connection to the project; (3) the installation of demonstration units that serve as a model for other local farmers; and (4) the program's great visibility and recognition across the country, which is simultaneously indicative of and a promoter of the program's methodology. In 2020, Balde Cheio was in operation in 478 municipalities in 21 Brazilian states (70% of the total federative units). A total number of 246 extension agents in training served a network of 1,626 dairy farms (293 demonstration units and 1,333 assisted units) covering 85,400 ha, supported by 182 partnerships.

Impacts on Embrapa were also reported. In Balde Cheio em Rede, in 2018, there was a consolidation of the methodology for training rural extension technicians in intensive dairy production; the inclusion of 13 additional units distributed across the territory; and the participation of more than 60 of its own employees. Important changes occurred from the structural point of view, with the segmentation into four component programs (management, training, sustainability and communication) (Malagutti et al. 2020).

A survey in Minas Gerais, the state with the largest number of farms participating in the program, showed favorable economic impacts, such as the ability to generate income from dairy farming. On average, the farms assisted directly by Balde Cheio generated BRL 197,842.70 (USD 37,590.11[8]) per year in 2016, that is, 2% of the gross amount generated by all dairy farming in the state that same year. Small and medium farms also had the opportunity to access a significant amount of financial resources that remain in the municipalities, generate income for other small businesses, and affect the local economy.

Some of the main results found in the *Report on evaluating the impacts of technologies generated by Embrapa* (Malagutti et al. 2020) following the Ambitec[9] methodology for the year 2020 were: (1) the cost/total revenue indicator fell to 62% on average in assisted farms, below the ideal minimum of 75%[10]; (2) productivity increased 3.8 times (from 1,180 liters/ha/year to 4,485 liters/ha/year); (3) economic impacts[11]: The internal rate of return was 1,260%; the benefit/cost ratio was 31[12]; the net present value was BRL 398,152,000 (USD 75,648,880); (4) in terms of socioeconomic and environmental impacts: Translated into aggregate indices ranging from −15 to +15, the program's major impacts, verified through interviews with farmers, were social (social impact index = 6.31), then economic (economic impact index = 4.14), then environmental (environmental impact index = 1.10).

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[8] According to the exchange rate on September 14, 2021, which has been applied to all currency conversions.

[9] Ambitec-Agro is a methodology developed by Embrapa to evaluate the impacts of technologies applied to agriculture and livestock using a set of 12 criteria and 65 performance indicators. Ambitec-Agro has three steps. The first is the process of gathering and collecting general data on the technology and the agribusiness segment to which it applies, including obtaining data on the scope of the technology (coverage and influence), the delimitation of the geographical area and universe of technology adopters. In the second stage there are questionnaires and interviews with selected adopters and the inclusion of indicators on an Excel platform, to give the quantitative results of impacts, impact coefficients and the environmental impact index of the selected technology. The third stage consists of the analysis and interpretation of these indices and indications of alternatives for managing the technology in order to minimize the negative impacts and increase the positive impacts, contributing to sustainable local development (Pinto 2020).

[10] The base year was 2016 for properties in Minas Gerais.

[11] The methodology can be accessed at: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/132174/1/MetodologiaReferenciaAvalImpactoEmbrapa.pdf

[12] Analyzing the series of costs and benefits from 2003 to 2020, the benefit/cost ratio discounted at 6% per year was 31.32, in other words, the benefits of the project were BRL 31.32 for each BRL 1 spent.

Based on 2003-9 data, the research by Novo et al. (2013) demonstrated that, on average, family farmers who joined the program as demonstration units and assisted units tripled their milk production and the average number of technologies and processes[13] applied by farmers was 21.7, which indicates the complexity and diversification of solutions adapted by technicians to each farm. The higher productivity was due to a combination of more lactating cows per area (31%), higher productivity per cow (24%), and better labor performance (37%) while using less land area (−7%).

According to interviewees, a great legacy of the Balde Cheio can be seen in its spin-offs. In addition to the many professionals who qualified, changing the lives of those extension agents, the model adopted by Balde Cheio was used to create the Bule Cheio Program for coffee ("Full Coffee Pot" – coffee in Rio de Janeiro). In São Paulo State, CATI, replicated Balde Cheio with the launch of the CATI Leite program in 2008; it follows the Balde Cheio methodology and uses technicians trained by Embrapa. Based on the success of Balde Cheio's proposed continued training, Embrapa has been adapting the methodology to other agricultural chains such as beef cattle (Bifequali TT), integrated systems (continued training in ILPF), dairy goats, coffee, bees, and others (Malagutti et al. 2020). In addition to Brazil, the program also expanded into other countries, with similar capacity-building actions in Colombia and Guatemala.

Analysis

Over more than two decades, Balde Cheio has consolidated itself as an innovative participatory technology transfer method that responds to the complexity of dairy activities, given the multiple interactions of soils, plants, climate, herd action, work and management. It is also appropriate for different farmer profiles (with priority given to family farmers) and delivers significant results in the sustainable intensification of dairy farming. As Novo et al. (2014) conclude, the program shows that it is possible for teaching and research institutions, which tend to prioritize the development of cutting-edge knowledge, to shift their focus to high-impact programs for rural farms, especially small ones.

The innovation's success lies precisely in the training process, due to its approach, excellent quality and focus on training extension agents. Without a defined strategy for scale gain, the project expanded in an organic way to around 500 municipalities in all regions of the country, driven by local and regional demand (i.e., bottom-up), establishing partnerships (Aragão and Contini 2021). Considering the scope of an institutional program, it has a wide coverage and representativity in the country, as it is present in the main producing states and municipalities. The impact evaluation of the program presented similar results among absolutely distinct regions, showing that the innovation is consistent, regardless of the farms' characteristics (soil and climate) or the initial stage of the assisted rural farm in terms of technology use (Malagutti et al. 2020). The project has the potential to serve different farm profiles (large, medium and small), but it seems to reach a greater number of family

[13] Some of the key technologies and productive process in Balde Cheio are: (1) rotational grazing of pasture (tropical species), which involves soil fertility management and division into small paddocks; (2) the use of sugarcane to supplement fodder whenever the climatic conditions limit pasture productivity; (3) simple administrative tools such as basic record keeping of financial and technical data, such as calving and breeding dates, individual monthly milk production and the reproductive calendar; (4) pasture irrigation and over-seeding of tropical grasses with oat and ryegrass; (5) the gradual introduction of improved breeds of dairy cows; (6) other complementary practices such as the use of by-products as concentrates, vaccination schemes, the culling of unhealthy animals, the restoration of natural vegetation on the margins of rivers and streams, the provision of sufficient shade during the day and grazing during the night.

farmers, due to their dedication, especially when women are directly involved (Novo 2021). Given the size of the country and therefore the range of environmental, social and economic conditions, Balde Cheio's success in the five regions demonstrates the capacity of the approach built to deal with complex problems, as it builds solutions that are adapted to each farm.

With regard to the process of scale gain, Figure 4 points to the following key factors: (1) the strong leadership of Embrapa researchers, especially Artur Chinelato and André Novo, from its inception to the present, who have led Balde Cheio with extreme dedication, building a clear vision of the organization's potential and the problems around technology transfer; (2) partnerships are another essential factor for implementation and scale gains, as the program depends on the partners' commitment to funding long-term training for rural extension technicians and their work with farmers; (3) the capability of the developed methodology to meet the needs of the dairy farming on different types of farm.

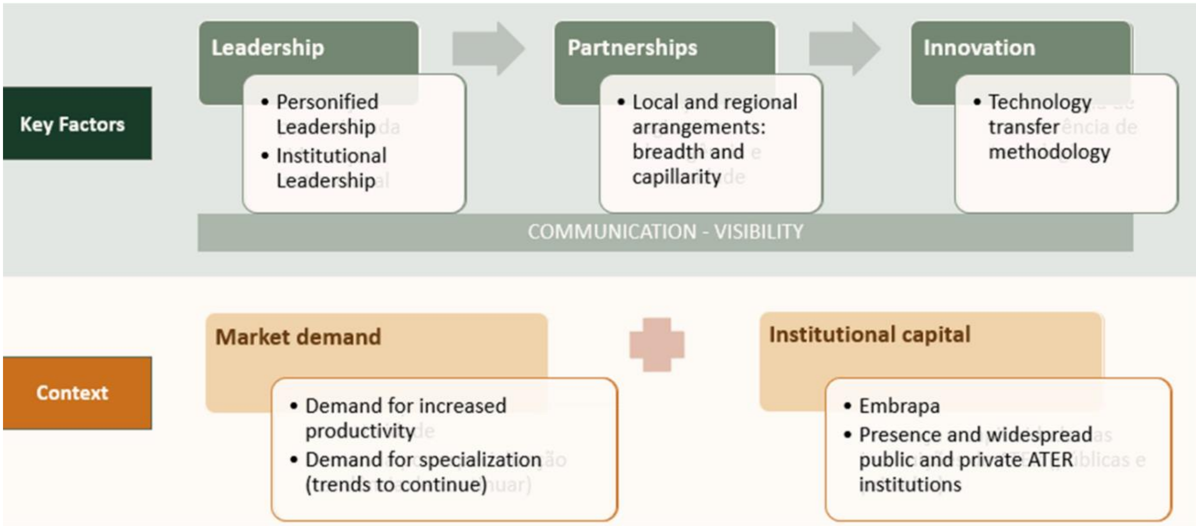

Figure 4. Balde Cheio's key factors.

It is important to highlight some factors in the Brazilian context that provided conditions for developing the program, such as institutional aspects: (1) the existence of Embrapa, a strong public agricultural research institution that is part of a consolidated National Agricultural Research System, with more than 2,400 researchers and an annual public budget; (2) the existence of technical assistance institutions (public and private) across the country.

It is estimated that 99% of municipalities in Brazil have dairy farms, comprising are more than 1.1 million farmers, mostly on family farm. In terms of revenue, the dairy industry ranked second in the country's main food sectors in 2018, and involves around 4 million workers (Novo et al. 2014). However, technical assistance institutions have a large deficit of technicians trained in dairy farm management compared to the size of the demand from the country's farmers. Thus, even after several years of Balde Cheio training extension agents continuously (Malagutti et al. 2020), demand for training extension agents in technologies for intensifying dairy farming is still very high (Novo 2021).

3.2 One Land and Two Waters Program (P1+2)

Description

The Brazilian semiarid region has a yearly rainfall of less than 800 millimeters (mm), an aridity index of less than 0.5 and a drought risk of above 60%, calculated between 1970 and 1990, covering an area of 1,128,000 km^2 with 1,262 municipalities (Ministérios da Integração Nacional e do Meio Ambiente 2004). It is one of the most populated semiarid environments on the planet, with 7.1 million people living in rural areas (IBGE 2019). It is often hit by droughts. One prolonged drought (1979-84) provoked immense internal migration and the looting of government warehouses, and estimates of deaths have been as high as 3.5 million people, especially the elderly and children (Lima and Magalhães 2019). About 400,000 families living in rural areas live in extreme poverty and are dependent on intermittent water sources, making them highly vulnerable to climatic shocks. The economy of the lower-income rural population is based on extensive cattle raising and low-income family farming, which declines sharply in periods of drought, even lead to livestock death and crop failure. About 60% of the municipalities in the semiarid region have a human development index (HDI) ranging from very low to low, and all of them have a lower HDI than elsewhere in Brazil (ASA n.d.).

P1+2 was created in 2007 to improve access to water for the production of healthy foods and guaranteeing food and nutritional security for the population of the semiarid region (Ministério da Cidadania 2020). (It built on the earlier social mobilization and training program for living in the semiarid region, One Million Cisterns (P1MC), which aimed to guarantee water for human consumption, starting in 2001.) In "P1+2", the "1" represents a plot of land and the "2" represents two types of water: The "first water", for human consumption, comes from the P1MC cisterns, and the "second water" is for agricultural production and animal husbandry. P1+2 operates in a decentralized manner (per family unit): A set of technologies adapted to the environmental conditions for water harvesting and storage combined with capacity-building activities and income transfer actions for productive inclusion and water stewardship.

In P1+2 the innovation is a bundle of technologies (water harvesting and storage structures) implemented through public policy, with the arrangement between government and civil society organized into a network.

The structures implemented by P1+2, although limited in water volume, created conditions for implementing family production systems that can guarantee the families' food sovereignty/security, in addition to providing mechanisms for generating income for the poorest families – producing small marketable surpluses. In addition, P1 +2 was developed to enable people to change their view of the productive potential of a region that is often considered inhospitable.

Since the late 1970s, Embrapa Semiárido has conducted research on rainwater harvesting systems. In the 1990s the Regional Institute for Appropriate Small-scale Farming and Animal Husbandry (IRPAA) and other NGOs started undertaking research and dissemination of rainwater harvesting technologies, as part of their Living in Harmony with the Semiarid Climate model, leading to the identification of the potential for adapting a Chinese public policy experience to the reality of the semiarid region.

China pioneered the installation and construction of rainwater harvesting and storage structures in water-scarce environments in Brazil on a large scale through public policy (Gnadlinger 2007; Duque 2008). The Chinese program, presented in Brazil during the 2nd Brazilian Rainwater Harvesting and

Management Symposium in Petrolina-PE in 1999, added to the experiences of civil society and research institutions in the Brazilian semiarid region, inspired and supported the structuring of P1MC and P1+2. Before P1MC, some rainwater harvesting structures had already been developed in the semiarid region. For example, cisterns had been built using prefabricated cement slabs in the semiarid region for more than 40 years, as a result of the initiative of a northeastern mason, Manoel Apolônio de Carvalho, who adapted the technique for building swimming pools, which he had learned in São Paulo, to create water reservoirs in the hinterland. However, these were dispersed and at a small scale (Costa, 2014).

In 2001, the Articulation in the Brazilian Semiarid Region (ASA[14]) formulated and started to implement P1MC. Two years later it became a public policy, part of the federal government's food and nutrition security policy, and it was one of the actions of the Zero Hunger Program, a mission-oriented policy[15] led by the National Secretariat for Food and Nutritional Security (Sesan) of the Ministry for Social Development and Fight against Hunger (MDS) (Campos and Alves 2014). In 2003, AP1MC was created, a civil society public interest organization (OSCIP), so that ASA could receive federal funds. P1MC's success lead into P1+2. The conceptual framework and methodology of P1+2 comes from the action of social movements and NGOs. The innovation lies in a set of social technologies[16] to harvest and store water developed to strengthen the ability to live in the semiarid region, implemented by an institutional arrangement involving the government and civil society. These technologies emerged from the processes of social mobilization and organization, political mobilization of family farmers and rural communities, and, above all, social movements with a cause in living with the semiarid climate (Santos 2017). The Living with the Semiarid Climate initiative is an innovative proposal, but not yet fully consolidated into the public agenda (Pires 2021).

Formatting the P1+2 technological package was led by the Social Technologies Network (RTS), created from governmental and non-governmental institutions in 2005 to foster collective organization for democratizing, accessing and building technological solutions that advance social inclusion, adopting "re-appliable products, techniques and methodologies, developed in interaction with communities and that represent effective solutions for social transformation as a concept of Social Technology" (FAO 2012). The main objective is to contribute to fostering sustainable development by disseminating and reapplying social technologies at scale, influencing the creation of public policies.

In 2005-6, RTS selected water storage technologies and consolidated a technological standard based on the technical feasibility of a basic project; it was financed by the Fundação Banco do Brasil. The technology selection process was based on the experience of technical assistance technicians of institutions participating in ASA, who identified existing low-cost and successful solutions, based on their longevity and benefits (Table 1).

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[14] ASA is a network of more than 3,000 different types of civil society organizations, such as rural workers' unions, farmers' associations, cooperatives, NGOs, OSCIPs, etc. It was established in 1999, during the Third Conference of the Parties to the United Nations Convention for Combating Desertification (COP3) and as a result of the parallel civil society forum, in which ASA was consolidated as an advocate of P1MC.

[15] Mission-oriented policies are systemic public policies that draw on frontier knowledge to attain specific goals (Ergas, 1987).

[16] A social technology consists of disseminating low-cost and easily replicable techniques for solving common problems, having been developed with the relevant community (Instituto Pólis and Fundação Banco do Brasil 2013).

Table 1. The main structures implemented by P1+2[17].

Boardwalk cistern	
Multipurpose underground cisterns (cement-plate tanks) with a capacity of 52,000 liters. Rainwater is collected from 200 m^2 catchment areas constructed near the cisterns. Photo: Gnadlinger (2020).	
Runoff cistern	
Multipurpose underground cisterns (cement-plate tanks) with a capacity of 52,000 liters. Rainwater is collected from road catchments or runoff. Photo Edna Santos (Embrapa database).	
Trench-like rock cisterns	
Trench-like rock cisterns are usually with 5 meters (m) wide, 4 m deep and 30 m long. Photo: Gnadlinger (2020).	

[17] For more detailed information about the technologies, including how to build them, see https://www.asabrasil.org.br/acervo/publicacoes

Roof cistern	
Multipurpose underground cisterns (cement-plate tanks) with a capacity of 25,000 liters. Rainwater is collected from roof runoff.	
Subsurface dam	
Subsurface dams, which are most appropriate in crystalline subsoils, store rainwater runoff. Subsurface dams have five parts: A catchment area, a storage area (also used for planting), a subsurface dam, a shallow well and a spillway. Photo: Gnadlinger (2020).	

Source: Agroicone.

P1+2 was started in 2007 as a demonstration project by ASA/AP1MC, financed by the private sector: Petrobras (Brazilian Petroleum Corporation) and Fundação Banco do Brasil (there were 818 beneficiary families[18] in 60 municipalities [Fundação Banco do Brasil 2013]). In 2008, ASA began the pilot project with more than 3,000 beneficiary families, with federal government funds.

Important adjustments were made in the first years of the program (2007-11) based on evaluations that identified recurrent problems with water pumps, the construction of cisterns, the correct management of water resources and in the dimensioning of production. In 2011, P1+2 was part of the federal government's Brazil Without Extreme Poverty Plan, and received a significant financial contribution. However, gains in scale were still not significant for financial reasons. From 2013 to 2016, P1+2 made a significant leap in scale when the MDS approved the National Program for Supporting Rainwater Capture and Other Social Technologies for Access to Water[19], which reduced bureaucracy and created clear rules for implementing the program.

[18] The beneficiaries were selected according to the following criteria: (1) they received the "first water" from P1MC; (2) they are available to test social technologies and disseminate them to the community; (3) they are an active member of the community; (4) they have land with suitable physical characteristics for the technologies (Fundação Banco do Brasil 2013).

[19] By means of articles 11 to 16 of Law 12873, dated October 24, 2013.

More than 100,000 P1+2 water structures were implemented in 2013-15. In 2016, there was a drastic reduction in the allocation of financial resources and a consequent reduction in the scope of the implementation of P1+2, due to changes in the country's political situation. In 2018, ASA secured resources from the National Bank for Economic and Social Development (BNDES) social fund for building over 6,800 production cisterns, implementing a new methodology for one third of the beneficiaries, and strengthening the technical assistance and rural extension services (ATER). By March 2020, 207,113 cisterns had been built by P1+2 (Ministério da Cidadania 2020). By the end of 2020, around 72% of the financial resources invested in deploying P1+2 were public resources. The funds were transferred to civil society institutions, initially through a partnership agreement signed between the federal government and the AP1MC under the control of the National Council for Food and Nutrition Security (CONSEA[20]).

Figure 5 highlights the main events and processes related to P1+2 scale gain over time. Only the cisterns financed by the Ministry of Cities appear in the graph, totaling 164,000 cisterns. Other sources funded another 42,000 cisterns, but there are no data available on the year of implementation. Note the BRL 3.5 million (USD 668,472) from PepsiCo in 2012 in other sources of funds.

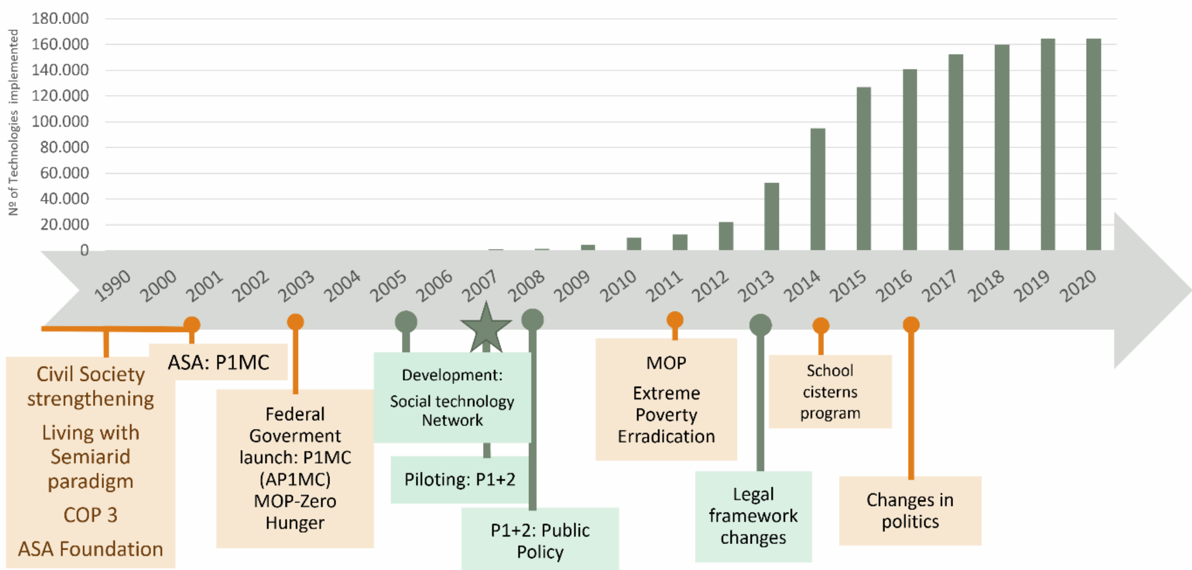

Figure 5. P1+2 timeline and number of cisterns implemented (cumulative by year).

Source: Agroicone, based on Ministério da Cidadania (2020).

Today ASA is working to create multiple sources of funding for the program to reduce dependence on federal government funding, seeking a methodology that explores resilient collective processes. However, there is a consensus that cutting funding for the programs represents a setback in the struggle and consolidation of the paradigm of living with semiarid conditions, because it can threaten the permanence of rural small farmers (Mendes Junior 2018).

[20] CONSEA brings the government and civil society together to propose guidelines for action in the areas of food and nutrition.

The way the program was set up with civil society and social movement leadership, the teaching instruments used, the valuing of the role of women and the deployment model can all be highlighted as the important components of the innovation. In addition to a widespread network of partners and executors, ASA/AP1MC has been efficient in financial accountability and management instruments, with the use of a management software (SIGA.net) to provide a clear and updated information base on implementation, enabling financial control.

Implementing the program involves the following steps: (1) social mobilization – selecting the communities involved and mobilizing the families, carried out by the (local) executive organization with the participation of civil society and local government representatives; (2) Collective training – the first one is on water management for food production (24 hours' training over 3 days); the second one covers the simplified water management system (24 hours' training over 3 days); (3) Implementation – the stage in which the technology is built or implemented with beneficiaries; (4) Transfer of production kit[21] – consisting of inputs, tools and investments in the property's physical infrastructure. Its content is defined in an agreement between the family and the implementing organization and has technical monitoring (assessment of the family's situation and its productive potential, and preparing the productive project); (5) Meeting among farmers – to exchange experiences of production techniques that are appropriate for the semiarid region.

The technologies are primarily offered to families experiencing poverty or social vulnerability in rural areas of the Brazilian semiarid region who are on the Cadastro Único[22] (CadÚnico) and already have water cisterns for human consumption (ASA n.d.). Families headed by women, with children aged 0-6 years, school-age children, people aged 65 and over and with physical and/or mental disabilities are prioritized (ASA n.d.), and have been since the start of P1+2.

Actions and actors

Embrapa Semiárido and the IRPAA had important roles in setting up the initial basis for the water harvesting and storage technology.

ASA played a pivotal role in the whole process, from developing the program's conception framework and its methodology, to its insertion into the federal government agenda and its implementation through AP1MC (the main institution responsible for managing the local organizations that operate as deployers).

ASA is a non-partisan organization that is governed by its own mandate. It has great mobilizing capacity as it brings together more than 3,000 grassroots organizations, including NGOs, farmers' unions, cooperatives, associations and church communities. ASA's mission is to strengthen civil society

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[21] The production kit has an approximate value of BRL 1,500 (USD 267), and is assembled according to each family's needs with items such as: vegetable seeds, fruit seeds, native plants, sheep and goats, poultry and swine, inputs and farm tools; infrastructure financing covers flowerbeds, bricks, chicken coops, shades, feeders, drinking fountains and other items, along with the irrigation systems within the financial resources available (Ministério da Cidadania/Secretaria Especial do Desenvolvimento Social/Secretaria Nacional de Inclusão Social e Produtiva 2021).

[22] Cadastro Único (Unified Registry) is a key instrument for the identification and socioeconomic characterization of low-income families to support public policies and programs aimed at fighting poverty. The Cadastro Único was created in 2001, and its database allows the government to identify the poorest and most vulnerable segments of the population. The system gathers data that is used to coordinate 20 social programs, thereby helping to select beneficiaries and manage policies that serve 27 million low-income families (WWP n.d.).

in building participatory processes for sustainable development in the semiarid region. Its actions are guided by the principles of participatory and decentralized management and by the vision of transforming the semiarid region into a food-producing region. Based on the experiences of different organizations, ASA states that living within the limits of the Brazilian semiarid region and particularly with droughts is possible, and what is needed are policies that relate to the region's realities. The right to water – as being necessary for life and an input for food production – is the unifying element of the network. ASA is present in the main participation forums for proposing and setting public policies.

ASA's representatives in each of the semiarid states are responsible for identifying municipalities' needs for water-related social technologies and forwarding them to ASA's central administration. In the 2000s, ASA launched the campaign under the slogan "No family without safe drinking water" and proposed P1MC, the successful implementation of which led to the development of P1+2.

One of the main reasons for the success of ASA's actions is a decentralized management system based on social networks that include communities. P1+2 has a national coordinator responsible for monitoring activities in the different states. In each state there is an organization, called the State Management Unit, that is part of ASA, and it is responsible for coordinating, monitoring and managing the project, both financially and technically. At the local level, the regional implementation unit is the organization that is responsible for the project in terms of mobilizing families, holding meetings and monitoring the implementation of social technologies. The regional implementation units represent different organizations such as NGOs, parishes, and rural farmer and worker organizations, according to local social dynamics.

The federal government is the other important actor, responsible for the scaling up of the program as the financial resources made available by the government are the main form of funding for P1+2 (72%). The program was included in the federal government's adopted public agenda to combat hunger and poverty, under the MDS, for its alignment with the objectives of fostering food security in the semiarid region. It is important to emphasize that the partnership between ASA/AP1MC and the federal government is the result of a long process of institutional progress in public bodies and civil society.

In this sense, the space gained by the paradigm of living within the limits of the semiarid region in federal governments in 2003-16 as a guide for strategies for access to water in the region, and the recognition of the importance of civil society's participation in implementing public policies, were decisive in getting P1+2 onto the public agenda, by defining the volume of allocated financial resources and the institutional arrangements for implementing the program.

Scaling up brought some challenges because of the increase in complexity. The program's contracting and financial processes, within the rules of the Tenders Law (8.666/1990) and the federal government's agreement model, became an obstacle to its implementation from 2007 to 2011. The legal framework for implementing P1+2 was the efficient response to this problem, formalizing a governance model that strengthens the relationship between the state and civil society in implementing public policies. The changes in the legal framework made it possible to formalize contracts by means of bidding waivers with private nonprofit organizations previously accredited by the MDS and conferred agility in accountability by shifting the focus from services to the final product (delivered technology): i.e. results based financing.

It is also important to stress that the gains in scale and the speed of implementation were only possible because of the ASA/AP1MC's operating capacity, which was able to absorb the increased complexity and volume of operations. AP1MC was structured to operate with transparency and to incorporate a large number of smaller organizations for final implementation, standardized procedures and supported execution with technical support. Despite the simplified institutionalized accountability with the legal framework, AP1MC continued to require tax receipts for all expenses incurred by the implementing organizations.

Today, due to the combination of dismantling public policies and the COVID-19 pandemic, there is an alarming increase in food insecurity in Brazil: Between 2018 and 2020 the number of people facing hunger jumped from 10.3 million to 19.1 million. In the northeast, food security affected more than 70% of households, reinforcing the relevance of P1+2 and social mission-oriented policies (Rede Penssan 2021).

Another challenge relates to changes in the Brazilian federal political scenario. Starting in 2016, the incoming federal administration drastically reduced the financial resources allocated to the program and abandoned partnership strategies with civil society. Until then, the scaling strategy had been developed and planned by the federal government together with the institutions represented by ASA and the implementing NGOs. From 2016, ASA has looked for other funders for the program, and the strategies include dialogues with state governments and water supply and distribution companies. In this sense, it is clear that the maintenance and continuity of a program at the scale of P1+2 depends on consolidating the paradigm of 'living with the semiarid' in state policy, beyond government cycles. It is also noteworthy that the current administration did not continue previously established public policies, especially those that had been set up with the organized participation of civil society; this is a setback for the concept of strengthening innovations aimed at being able to live in the semiarid region.

3.2.3 Outcomes

From 2007 to 2020, P1+2 significantly expanded access to water for more than 200,000 socially vulnerable families in the semiarid region (Ministério da Cidadania 2020). Some municipalities in the semiarid region installed cisterns for production inspired by the results of P1+2. However, there are no figures available, and the work was carried out directly by public bodies, in other words, the element of linking with civil society was not replicated.

Today, the total cost of implementing a 52,000-liter cistern is around USD 3,384 (2021[23]) (having been USD 1,600 in 2008), and this includes the operational costs, mobilization and capacity-building activities. More than BRL 2 billion (USD 382,000) has allowed the implementation of 207,113 technologies over 12 years, mostly through public funding. About 74% of the cost of each cistern goes to labor and materials. The balance (26%) covers the costs of mobilizing, training, technical assistance services and purchasing the production kit.

Despite the apparently high cost of the structures, it is important to consider: (1) that there are no maintenance costs for the state, since the cisterns are the families' responsibility; (2) the long life span of the structures – some cisterns are 40 year old; (3) the indirect benefits of food production to the public health system due to the improvements in family nutrition; (4) the high cost of emergency

[23] During the pandemic.

actions in periods of drought, including the distribution of water and food to vulnerable families. For example, the operation of a water truck during periods of drought costs the public coffers between USD 107,000 and USD 178,000 annually.

The Cisterns Program, which combines implementing cisterns for human water consumption and food production (P1MC and P1+2), is not enough to end the need for emergency supply by water truck. However, it does reduce the need and the logistics costs, as trucks can fill the cisterns directly instead of having to distribute the water in buckets and other makeshift containers.

The increase in the availability of water has allowed the beneficiaries to expand or start food production – domestic gardens or small livestock production – for family consumption, improving their diet, in terms of quantity, variety and quality (due to agroecological based production). Building the cisterns significantly transformed the beneficiaries' lives, especially the women's, who took the lead in running productive gardens, having gained hours from time previously spent fetching water. In addition, there was an increase in income generation and economic benefits from saving on food expenses (Pires 2021).

Income generation proved to be both an opportunity and a challenge, due to the very small scale of production made possible by the cisterns. According to Gnadlinger (2020) 5,200 liter cisterns allow the supplemental irrigation of fruit trees and small vegetable beds (60 m^2). The P1+2 cisterns show farmers the productive potential of the semiarid region, motivating some to build other cisterns with their own resources in order to expand production. According to ASA, most of the beneficiaries have been able to maintain the cisterns, despite the limited results in direct income generation. From ASA's point of view, the indirect economic gains of food production need to be considered for an accurate assessment (Pires 2021). In general, the abandonment rate is low and families in general value and maintain the installed technologies (Pires 2021).

Social mobilization and training for decentralized water management contributed to expanding the impact and social gains from the technology and, therefore, need to be maintained and deepened. The main limitations and deficiencies are linked to the insufficient technical training for proper use, maintaining and monitoring the technology and its use. There is need for better monitoring, and better and more complete training on cistern and production system maintenance.

More in-depth training, which fosters the absorption of knowledge and the sense of importance of maintaining the cisterns for advancing food security and family income generation, are essential for continuity when users no longer have follow-up from the program. Better results were achieved through a 1-year follow-up by ATER institutions (monitoring the built structures, deepening technical assistance for optimizing the families' productive systems) for the last phase (2018).

Despite the gains, it is important to say that the program is not enough to eradicate vulnerability, so the families' permanence on the land is still threatened. Reducing social and environmental vulnerabilities requires broader and more transformative approaches that go beyond distributing water infrastructure.

Analysis

The country's political context has hugely affected the implementation of P1+2 and its scalability (Pires 2021). P1+2 has involved considerable amounts of public funding, mostly from federal government, with smaller amounts from the private sector and regional governments. Four successive governments, from 2003 to 2016, chose combating hunger (Zero Hunger Program) and extreme poverty (Brazil Without Extreme Poverty Plan) as a priority. These two mission-oriented policies created the conditions for renewing paradigms in water supply policy in the semiarid region and the implementation at scale of P1+2. Through the public policy the cisterns went from the experimental scale to an ambitious large-scale program reaching more than 200,000 families through an investment of USD 356 million. The big push in state public investments in policies for living within the limits of the semiarid region came to a standstill in 2016, due to political instability in Brazil. This entire process has involved major changes in managing social public policies for Brazil's semiarid region, with a reduction in the resources for funding new experiences and the dissolution of ministries that were strategic for the sustainable development of small rural farms in the region. Examples included MDS and others, leading to significant cuts in the financing for the initiatives for living with the semiarid zone, including P1+2 (Mendes Junior 2018), which put their sustainability and continuity at risk.

Figure 6 shows the main factors for P1+2's development and scaling process: (1) developing technology as a social technology package adapted to regional conditions (bottom-up innovation); (2) ASA's leadership and organizational capacity; (3) partnership between civil society organized into a network and the federal government, which mobilized resources and modified legislation (use of results-based payment strategy) allowing the implementation at scale in decentralized way.

Factors relating to context also need to be highlighted: (1) the national context: Alignment with mission-oriented policies established the project's prioritization; the increase in democracy in the period made it possible to integrate a civil society proposal into public policy; (2) the international context: The emergence of the environmental and climate agenda, more specifically the fight against desertification, strengthened the paradigm of the ability to live in the semiarid region and consolidated ASA's mission; (3) the existence of local organizations that could mobilize farmers combined with a greater openness of public administration to joint action; (4) the relevance of innovation to the needs of people living in the semiarid region, especially increasing their resilience to social vulnerabilities – poverty, food insecurity and climate change.

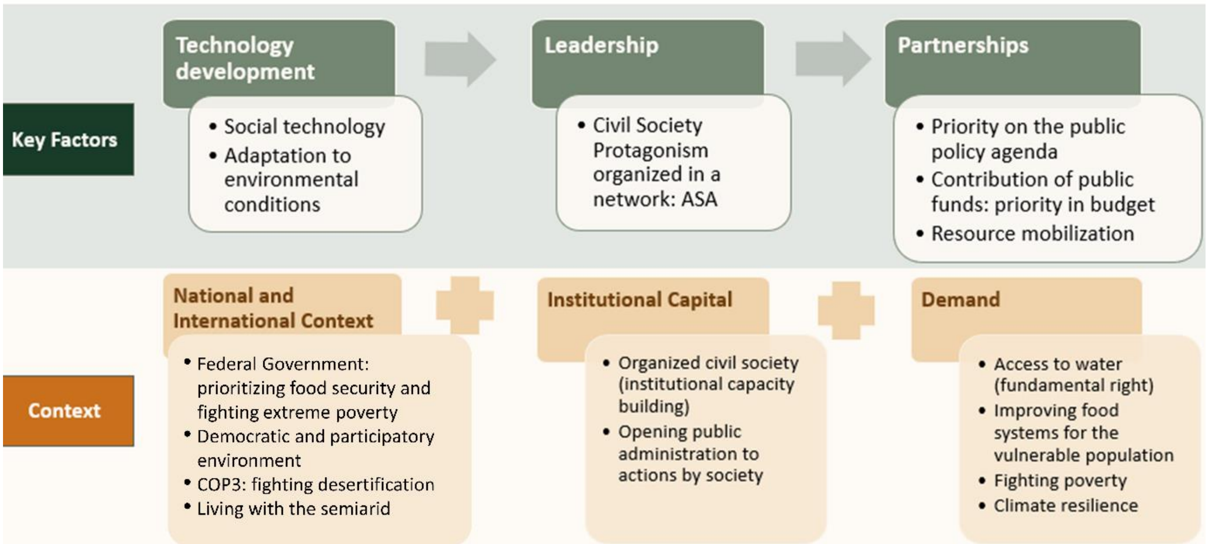

Figure 6. P1+2 key factors.

Although the program has not been implemented outside the semiarid region, the model for implementing public policy and the arrangement between government and civil society can be generally applied. Deploying this program shows other possibilities for action in terms of public policies. When society mobilizes and organizes itself, it can contribute very effectively. In recent years, other policies have been implemented using this model of participation by members of the general population in monitoring government actions.

The institutional arrangement between the federal government (the main funder), the AP1MC (the managing OSCIP) and implementing NGOs organized into a network is one of the innovative factors in the implementation of a public policy at such a scale. Adjustments in the contractual and financial format for P1+2 was fundamental for scaling up. The creation of the legal framework enabled a new financial mechanism, which allowed transparency in processes and inspection, as well as the necessary agility in contracting third-party services for implementation at the endpoint and guaranteeing the program's transparency and accountability.

The social technology format associated with the development of local capacities facilitates its ownership by the beneficiaries and the maintenance of the equipment. Associated with the equipment, the offer of the production kit (to support the implementation of a new production system), training in water management and agroecological production, exchanges for developing the families' productive capacities, technical assistance and rural extension monitoring (only in the final phase), also contribute to the positive results of the initiative (ASA n.d.).The infrastructure costs are relatively low considering the benefits and the long life span of structures: A cistern can last decades, diluting the cost over time. P1+2 allows people to manage the available water resources, which is a cheaper alternative to large water infrastructure and emergency water distribution. The resources allocated to P1+2 also reduce the costs of healthcare and other public policies that deal with the harmful effects of population migration to large urban centers.

The set of social technologies developed for poor families enabled a model of food production and small livestock production for families. Overall, the beneficiary families, especially women, experienced a positive change in their lives. In a way, the situation of the semiarid regions represents the reality of many small farmers around the world who lack some type of resource. So programs like P1+2 are of great relevance for improving the lives of many and should therefore be prioritized by international cooperation, investors and aid agencies.

ASA/AP1MC (and the network of institutions they comprise) was and remains fundamental to the success of P1+2. The network was essential for the successful execution and scaling up of P1+2, as it combined widespread coverage of the semiarid region and local knowledge for fostering an efficient beneficiary mobilization and selection. It also created better conditions for integrating other government actions that enhance the benefits of access to water for a productive system (such as ATER, public procurement, etc.). ASA's efficient management enabled up-to-date monitoring of the use of resources and the delivery of technologies, also contributed to generating information and evidence of the project's positive results.

3.3 Integrated production systems – integrated livestock and crops (ILP) and integrated livestock, crops and forest (ILPF)

Description

Integrated systems are a production strategy that has been growing in Brazil in recent years. They comprise the use of different productive systems – agricultural, livestock and forestry – within the same area. They can be done simultaneously, in succession or in rotation, and the benefit is mutual for all activities.

Embrapa began the research on integrated systems in the 1980s. The initiative of adding agricultural crops to the rotation for the recovery of soil under pasture emerged at that time as a strategy for reducing the recovery cost of degraded pastures in the Cerrado biome. The main bottlenecks in cattle raising in Brazil include the lack of adequate management, effective soil management, low level of investment. In this context, in the 1980s and 1990s Embrapa developed the Barreirão and Santa Fé systems. The Barreirão system is a set of technologies and practices for the recovery of degraded or unproductive areas, based on the rice-pasture system. The Santa Fé system also uses annual crops (usually grain) and pastures, but the focus is on the production of hay as a source of organic matter for direct planting systems for annual crops (Embrapa 2020). The innovative aspect of this system is the application of crop-livestock integration concepts with the direct planting systems.

The addition of forest component to integrated systems only began in the 2000s to meet the demand for wood and the need to reduce heat exposure of the animals.

The year 2009 marked a major turning point for developing and scaling up the ILPF system. At COP15, in Copenhagen, Brazil made a voluntary commitment to reduce greenhouse gas emissions by 2020. As a development of the Copenhagen Agreement, the National Climate Change Policy was established in Brazil (Law nº 12.187/2009). In the bundling of provisions for meeting the commitments, the National Climate Change Policy created specific credit and financing lines by public and private financial agents for the ILPF system, and the development of research lines by funding agencies. The law also provided for the establishment of Sectoral Plans for Mitigation and Adaptation to Climate Change, including the Low Carbon Agriculture Plan (Plano ABC), in which the ILPF is one of the focus areas for action. The National Climate Change Policy marks the start of the fight against climate change on the agenda of the Brazilian state and ILPF as one of the strategies for decarbonizing agriculture, consolidating the path to scaling up this innovation.

Plano ABC was launched in 2010 and approved in 2011. It provided, among other actions, for increasing the adoption of ILPF and agroforestry systems in 4 million ha. In the same period, Programa ABC was also created, which is a credit line to finance projects aimed at adopting practices that reduce greenhouse gas emission from agricultural activities, such as the ILPF system. The BNDES ran the program. That same year, the ILPF Network was officially created, formed and cofinanced by Embrapa and the private companies Banco Bradesco, Ceptis, Cocamar, John Deere, Soesp and Syngenta, with the objective of accelerating the adoption of ILPF technologies (i.e., gaining scale) (ILPF Network 2019).

In 2018 the ILPF Network became an association, and a legal structure was adopted for expanding the network's operations, facilitating the entry of new companies and raising international funds.

In 2021, ABC+, the new phase of Plano ABC, was announced, and its strategic agenda (proposed by the Brazilian government) extends the sectoral policy for combating climate change in the agricultural sector from 2020 to 2030, ratifying the promotion of production technologies that were already ABC's focus (MAPA, 2021).

The ILPF Network currently supports a national network with 16 technology reference units (URTs) and 12 technology and research reference units (URTPs), distributed across Brazilian biomes and funded by public and private companies (Figure 7). URTs and URTP are public or private production systems, aimed at validating, demonstrating, transferring technologies, training technicians, and communication. More recently, in 2020, the network prepared a protocol for certifying sustainable properties using around 120 production indicators, to give more visibility and possibly add value to the production arising from these systems.

Figure 7. ILPF technology reference unit in Minas Gerais.

Photo: Maria Celuta Machado Viana.
Source: Skorupa, 2017.

Implementing ILPF technologies depends on individual investment by rural farmers. Due to the high cost of ILPF implementation – around BRL 4,000 (USD 764)/ha (Embrapa, 2019), the majority of projects are financed with rural credit for funding and investment through regular credit lines and, as of 2013, a specific credit line with a subsidized interest rate. Since 2013, regular interest rates average 8% p.a. and subsidized rates are 5% p.a. Despite credit for financing system implementation having increased from 2013 to 2020, the number of Programa ABC contracts for ILP/ILPF implementation is still low: Only 1,550 contracts were signed in that period, totaling BRL 1 billion (USD 190,992,000). Despite Programa ABC being the line created for financing emission reduction technologies, other lines, such as PRONAF (a line specifically for family farmers with better interest rates), are also used, in addition to the farmers' own capital, which represents the main source of financing.

According to those interviewed, improvement in pasture productivity is already clear in both ILP and ILPF after 1, 2 and 3 years, accompanied by an increase in grain productivity. The costs and returns of the systems depend on a set of factors, such as farm and local conditions. However, a study conducted by Embrapa using a cost standardization methodology showed that the return on investment in four URTs that adopted integrated production systems such as ILPF was greater compared to farmers who used exclusive crop or livestock systems.

According to the ILPF Network, in 2010-21, the total area of ILP and ILPF in Brazil increased by 216%, from 5.5 million ha to 17.4 million ha (ILPF Network 2021). It represents 7% of the total area under agriculture in Brazil, which is 240 million ha (167 million ha of pasture and 77 million ha of crops and planted forest).

The scale gain achieved in recent years has been the result of sets of actions, such as creating (1) URTs, (2) the evolving research by Embrapa and later by other research institutions, (3) creating the ILPF and innovation cofinancing by other financial institutions such as Banco do Brasil and private banks, (4) creating the ILPF Network Association, (5) seeking to expand partnerships and new financing sources and, more recently, (6) the launch of ABC+, ratifying Plano ABC's objectives for 2020-23. The bundling of ILPF and public policies (National Climate Change Policy) through the Plano and Programa ABC is the main pathway for the scaling up process since 2009. The ILPF Network combined with URTs is a complementary innovation created to support the core innovation, ILPF, in this process. Figure 8 shows the scale gain (ILPF Network 2021) and the main milestones in ILPF's trajectory.

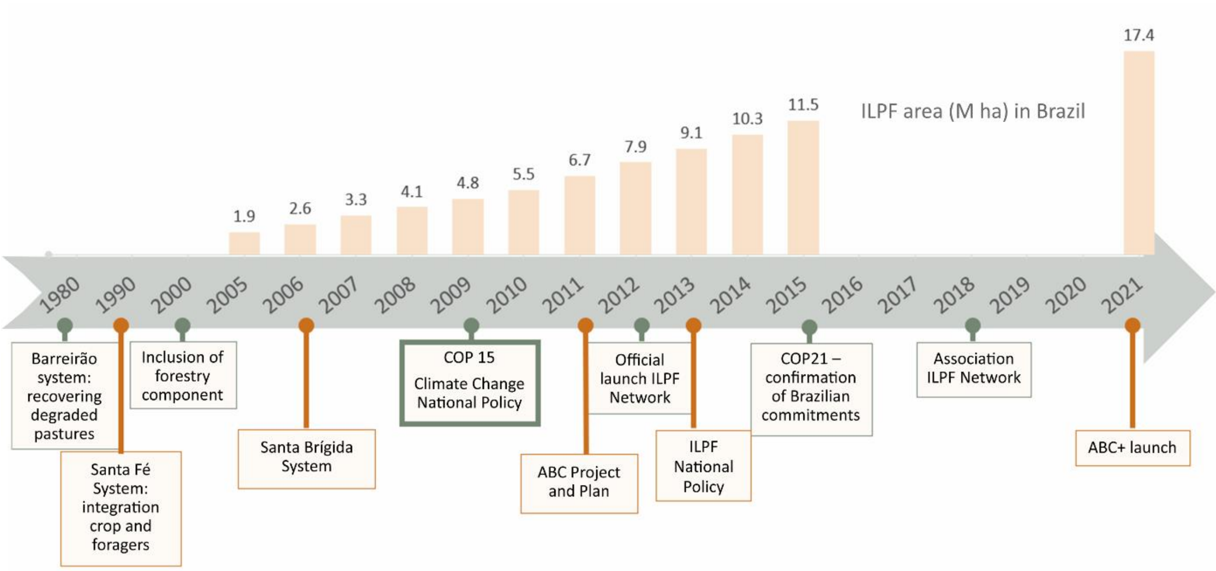

Figure 8. ILPF timeline and ILPF area in Brazil.

Source: Agroicone, based on ILPF Network.

Actions and actors

Four actors have had important roles in developing and implementing ILPF. They are: Embrapa, farmers, government and the ILPF Network.

Embrapa had a pivotal role in developing ILPF's technological solutions from 1980. It has been responsible for engaging and establishing partnerships with farmers (early adopters) and cooperatives to implement pilot units and for continuing technological improvements. Additionally, Embrapa coordinates the ILPF Network, a public–private association for supporting ILPF dissemination and implementation.

Among farmers, the early adopters were larger farms. By testing the innovation with larger farms, their adoption brought important contributions to the innovation process. Early adopters were also important to show the practical feasibility of solutions developed by scientific research. Embrapa's recognition and credibility, combined with the search for greater financial returns for farmers, were key factors in implementing the demonstration units. Many farmers look to Embrapa for alternatives for improving production and financial returns. Some characteristics of the early adopters (mostly large and medium farms) that contributed to ILPF innovation and visibility were their high level of education and/or technical orientation, managerial capacity, capital, and access to the financial market, as well as tolerance of risk.

Government agencies – MAPA, the Ministry of the Environment (MMA) and the Ministry of Finance (MF) – were responsible for ILPF bundle solutions, in the design of the National Climate Change Policy and the sectoral plan (Plano ABC). ILPF was incorporated as a sectoral strategy to comply with international commitments to reduce greenhouse gas emissions with the consequent investment in specific rural credit lines. The existing structure of public banks capable of initially operating credit, the availability of subsidized resources from rural savings, constitutional funds, also played an important part in disseminating innovation.

ILPF Network and ILPF Network Association Partners, which were established and cofinanced by Embrapa and the large private companies Bradesco, Ceptis, Cocamar, John Deere, Soesp and Syngenta, act to accelerate the broad adoption of ILPF technologies by financing projects, research and technology transfer and holding events to promote ILPF and the technology. The network's goal is to foster the expansion of ILPF to 30 million ha by 2030.

3.3.3 Outcomes

The results of integrated systems are difficult to measure, since they can change due to factors such as regional conditions, the system implemented and the inputs used. The results achieved by farmers using ILPF are: Increased production of grain, beef, milk, wood and non-wood products in the same area; optimizing and intensifying soil nutrient cycling; maintaining biodiversity and agricultural sustainability; increases in farmers' net income due to the diversification and increase in production; improved animal welfare due to the greater thermal comfort provided by the shade of trees; improved quality and conservation of the soil's productive characteristics; economic stability with lower risks and uncertainties due to production diversification; optimized production processes and factors, and mitigation of greenhouse gas emissions (ILPF Network 2019).

However, there are also challenges to be overcome, including: (1) the high level of labor and technology required from rural farmers to manage the integrated systems (strategic, tactical and operational complexity); (2) resistance to adopting new technologies (unknown, cost of initial investment and cultural); (3) greater need for capital and infrastructure (machinery, energy, transportation systems, etc.); (4) longer payback time in the case of forest investments; (5) lack of specialized technical assistance.

According to a survey conducted by Kleffmann Group in 2015-16, there was an increase of close to 10 million ha in the area occupied by ILPF in 2005-15, with 11,468,124 ha of land in Brazil dedicated to integrated agricultural production systems in 2015 (ILPF Network 2019). This is equivalent to about 5.5% of the cultivated area that year, with 83% in ILP system, 9% in ILPF and 8% in other models of integrated production systems. In 2010-15, the 5.96 million ha increase in integrated systems (higher than the target set in Plano ABC) accounted for the sequestration of 21.8 million tons of CO_2eq. According to the IBGE (2007, 2019), there were approximately 491,000 farms using agroforestry systems in 2017, representing an increase of almost 61% compared to the previous census in 2006. In terms of area, there were 13.86 million ha in 2017, approximately 66% more than in 2006. From recent data published by the ILPF Network it was estimated that ILPF in Brazil have achieved 17.4 million ha (ILPF Network 2021).

In addition to the direct results, there also are indirect results, which include: Generating direct and indirect jobs; reducing seasonality in rural labor use and rural exodus; reducing pressure for cutting down new areas of native vegetation and improvements in the image of farmers with the public (ILPF Network 2019).

According to the impact assessment of ILPF systems carried out by Embrapa (Rodrigues 2017), an increase in agricultural input application for fertility and pest control purposes was observed in six URTs where ILPF was implemented (average performance index = −0.42). There were significant increases in grain yield and weight gain for a larger number of animals (average performance index = 5.2, with a range of −15 and +15), resulting in a positive technology index performance. The average social and environmental performance index was also positive (6.86 for the criteria set): 7.59 for economic aspects (income generation and farm value) and 6.15 for social aspects (capacity building, employment opportunities, quality of jobs and equal opportunities and rewards across genders, generations and ethnicities), indicating high contribution to sustainability.

Therefore, ILPF systems generate benefits across society. Consumers have access to cheaper and higher-quality products. Society benefits from lower greenhouse gas emissions. By producing more competitive commodities, Brazil benefits from a better balance of trade. However, it is important to remember that expansion in commodity production can lead to reduced average prices, harming the profitability of vulnerable farmers.

Analysis

ILPF can be adopted in different ways, with numerous crops and various animal species, adapted to regional characteristics, weather conditions, the local market and farmers' profiles. According to the IBGE (2007, 2019), there were around 491,000 farms with agroforestry systems in 2017, 30% of which were smaller than 10 ha (and of these the majority are agroforestry farmers), 57% of which cover 10–100 ha, and 13% of which are larger than 100 ha. Additionally, farmers who are more likely to adopt the technology are those with higher educational levels, better financial situations, good farm structures and access to technical assistance service and rural extension (Noce 2017).

The Brazilian political context in the late 2000s and early 2010s was extremely favorable for scale gain in innovation, thanks to the National Climate Change Policy, launched Plano ABC and created Programa ABC, which provided for significantly increasing the adoption of ILPF systems in the country. With the announcement of ABC+ in 2021, the Brazilian government continues its sectoral policy for combating climate change in the agricultural sector in 2020-30, ratifying the advance of production technologies that were already the focus of Plano ABC. This context, combined with the development of technology, visibility, partnership and leadership, explains the ILPF scaling trajectory (Figure 9).

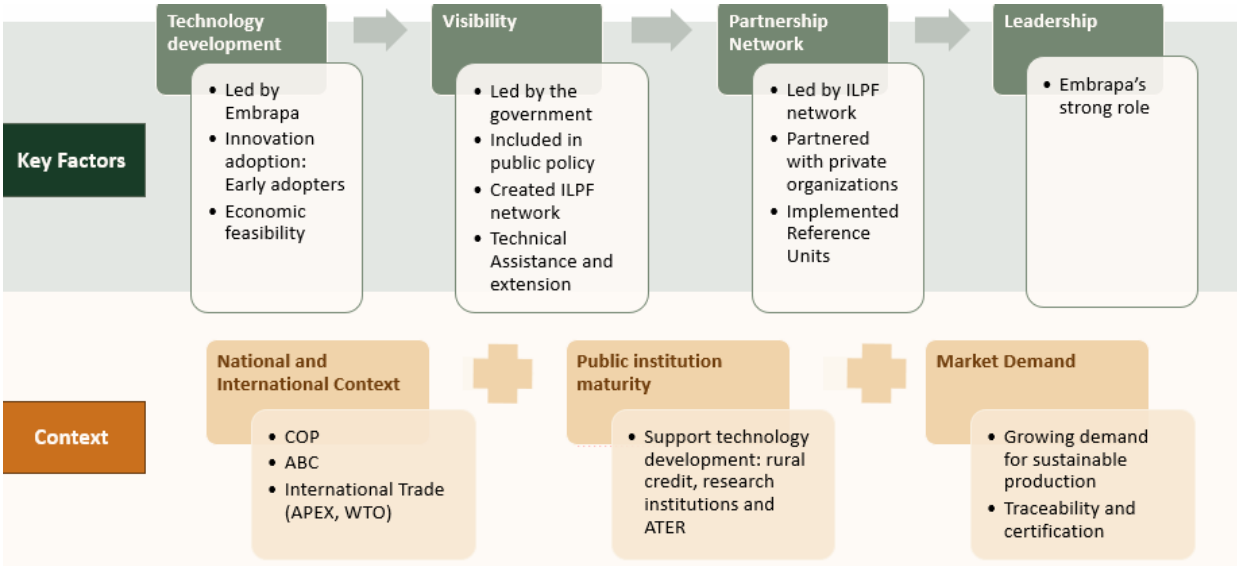

Figure 9. The key factors of ILPF.

This program has a potentially huge impact on the way that Brazil is decarbonizing its agricultural system using a climate-smart approach. ILP and ILPF bundle technology, agricultural policies, strategies and approaches that help agriculture move to sustainability, with lower carbon emissions and lower impacts.

The inclusion of ILPF as one of the Plano ABC tools shows how Brazil is addressing the complex issue of increasing food production and its world leadership in food production. Brazil is presenting a strategy that integrates productive, environmental and social components by diversifying production, employment and income generation, soil conservation, better use of natural resources and inputs, reducing pressure for opening new areas, as well as increasing animal welfare and greenhouse gas mitigation.

Additionally, institutional partnerships with public technical assistance institutions are seen as essential for scale gain, expansion success and continued innovation (Rodrigues 2021). In addition to Embrapa, large private companies are partners of the ILPF Network and members of the ILPF Network Association. The corporations' motivation is to foster initiatives aligned with sustainability goals, driven by the international environmental agenda as well as the business opportunities. For example, one of the commitments of Syngenta's environmental plan is to improve the conditions of 10 million ha of degraded land and supporting ILPF implementation has been the strategy for achieving this target.

The efforts of research and rural extension institutions involved in disseminating ILPF have showed some success, but they are still far from achieving their adoption potential. In the Cerrado biome alone, there are 10.8 million ha of degraded pasture that would benefit from integrated systems.

Since the beginning of Plano ABC and Programa ABC (credit), ILPF has gained visibility, initially from universities and research institutes and later from financial institutions. However, there is still a bottleneck in ILPF funding, due to the difficulty in finding technicians who are capable of supporting farmers in implementing and designing a project for obtaining credit (ILPF Network 2019).

The rural credit system was designed to finance different items (fertilizer, seeds, machinery, operations, etc.) separately, to be allocated either to livestock or other agricultural activities. Consequently, financing a technological transition involving integrated systems was not a good fit for the credit system, requiring complex adaptations by the banks, so that the whole of the integrated system could be financed. The advent of specific lines of credit for ILPF (through Programa ABC) as of 2012 addressed this problem, adjusting contract allocation and interest and payment terms. However, the bureaucracy and lack of knowledge of producers and technicians for accessing the Programa ABC credit line is still a problem and explains the low uptake by producers.

The inclusion of ILPF technologies at the center of Brazilian climate change strategy was the main factor in scaling up ILPF. The development of public policies and credit lines, and the creation of an institutional governance through the ILPF Network were very important for establishing partnerships, obtaining investment and engaging farmers.

3.4 Agrosmart: digital irrigation monitoring system

Description

Agrosmart is a Brazilian start-up established in 2014 that offers a decision support platform to provide agronomic insights for the entire agribusiness supply chain with the objective of helping farmers achieve a higher level of water use efficiency.

Agrosmart's core innovation is Aqua, a digital solution for monitoring irrigation. The package works with three main components: Hardware, data science and a data access platform. The hardware includes equipment developed by third-party companies, which consists of: (1) a weather station for real-time monitoring of precipitation, temperature, relative humidity, wind direction and speed, solar radiation, dew point and evapotranspiration; (2) a digital rain gauge that is updated every 15 seconds; and (3) a soil moisture sensor. The data science consists of agricultural and meteorological modeling that, with the input of data from sensors collecting local data, calculates the optimum irrigation depth and the best time to irrigate. Finally, in the data access platform, the data already analyzed are delivered as actionable insights for farmers. Aqua generates intelligence through a data integrator platform, to provide customers with easy-to-use forecasts and information using an application on their mobile phone and (PIB 2020).

The idea of the platform was developed at the Federal University of Itajubá-MG's business incubator, a year before Agrosmart was established. The multidisciplinary team consisted of a business administrator, a graphic designer and an electrical and electronics engineer. The prototype was made in 6 months, using financial resources from Agrosmart, the university and ESALQTec[24], and consisted of a radio frequency network that communicated between sensors installed in the field and, from a set point, communicated with the system. The second and third versions of the connected sensors were supported by SEBRAE (PIB 2020). At the beginning, the implementation was informal and on a small scale, and there was much improvisation and testing. In the testing and validation processes, the team set up several pilots in different crops, and found that transmitting only the raw data from

[24] A start-up based at the University of São Paulo.

the sensors to farmers would not generate a usable product, thus identifying the need to deliver processed information such as practical recommendations.

In 2014-16, a water crisis in Brazil's southeastern region generated major losses in agricultural production. Taking advantage of the opportunity to offer a solution to save water and energy for irrigation, Agrosmart presented the idea and the prototype of the digital monitoring system and won a national start-up contest[25] in 2014, receiving public funding for research and product development from public institutions[26], in addition to financial resources and guidance from two accelerators for structuring the company[27].

The beginning of the company scaling up was in 2017, when it began receiving more orders due to the greater visibility given by investors. The scaling up continued when, in 2019-21, the company received BRL 22 million (USD 4,180,000[28]) from Bradesco's InovaBRA Fund and Positivo's corporate venture, moving from the seed stage to series A funding[29], the first major barrier to be overcome in a start-up's journey toward growth. Over the years, new data have been integrated into the system, such as satellite image analysis, weather forecast data and agronomic modeling on pests and diseases. Agrosmart now has big companies as clients, including AB InBev, Cargill, Coca-Cola, Corteva, Nestlé and Syngenta. In April 2021, the company acquired BoosterAgro (Exame Agro 2021), an Argentinian start-up that developed one of the most popular agrometeorological apps in the region[30]. In the coming months, Agrosmart expects to analyze 10 new companies for possible acquisition. The next step, according to the CEO, is expansion to Asia and Africa (Dias et al. 2019). Figure 10 presents a summary of the main events and processes in developing innovation and scale gains. In 2021, in a short time, agtech reached the milestone of 800,000 ha monitored by the company's sensors.

[25] The contest was organized by the Ministry of Science, Technology and Innovation.
[26] FAPESP (São Paulo Research Foundation) and FINEP (Funding Authority for Studies and Projects).
[27] Baita: https://www.baita.ac/
[28] According to the exchange rate on September 14, 2021.
[29] A series A investment is the company's first significant round of venture capital financing – a critical stage in the funding of new companies. It is usually the first stock issued after the common stock and common stock options issued to company founders, employees, friends and family and angel investors.
[30] The financiers include Baita, Bradesco's InovaBRA Fund, Positivo's venture capital corporate arm and SP Ventures.

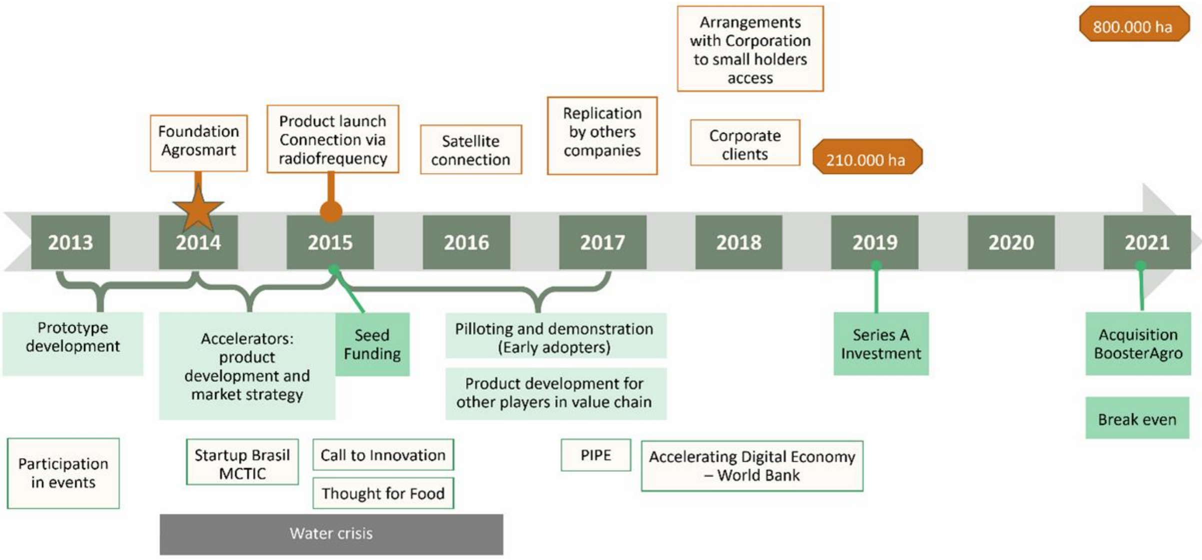

Figure 10. Agrosmart digital irrigation monitoring system (Aqua) timeline.

Source: Agroicone, based on Agrosmart (2021).

The company has two lines of business: One geared to farmers and the other geared to the corporate area. Currently, farmers are offered products that are more mature and standardized (off-the-shelf products), and corporate customers, depending on their size, can access differentiated products and services, with greater possibilities for customization. According to Marcus Sato (Head of Technical Sales at Agrosmart), the company also uses the white-label model[31] to sell to other companies.

In general, customers rent equipment (ground sensors, weather stations) and pay for services (data collection and processing) on a subscription basis. Due to the equipment's costs and coverage area, it is more feasible for medium-size and large farms (more than 200 ha). The annual subscription for accessing the platform varies from BRL 180 to BRL 500,000 (USD 34.2 to USD 95,000), depending on the size of the crops and the level of intelligence and complexity of the services. The average is BRL 40,000 (USD 7,640) per year (Brazil Journal 2019). To overcome farmers' resistance to new technology, Agrosmart's initial strategy was to demonstrate the system's efficiency with pilots (Itaú Mulher Empreendedora 2016).

Agrosmart also partners with industry. For example, with agricultural input industries, it offers discount programs targeted at farmers, combining input consumption with purchasing irrigation monitoring services. Food industries, on the other hand, introduce the start-up's services in their suppliers' production to monitor production processes. This in order to access supply indicators and provide traceability and/or certification or enable better brand positioning in relation to environmental sustainability and climate change (Agro Bayer Brasil 2021). For example, in partnership with Nestlé and Hanns R. Neumann Stiftung Foundation, Agrosmart works with 15 small coffee farmers to accelerate adaptation, climate resilience and the adoption of climate-smart technologies in a changing climate landscape and situations of scarce resources. Part of Nestlé's motivation is to

[31] A white-label product is a product or service produced by one company (the producer) that other companies (the marketers) rebrand to make it appear as if they had made it.

reduce the carbon footprint of some of the company's products. Agrosmart also develops partnerships with research institutions (e.g., Embrapa) to expand the range of products, in addition to developing partnerships with other companies to expand access to distribution channels. NaanDanJain, a global leader in drip irrigation systems, is a strategic partner, enabling Agrosmart to access more than 900 dealers in Latin America.

Agrosmart's identity is built on the concepts of sustainability and climate resilience, which attests to the influencing context (the climate emergency) for the company's marketing strategies and vision. Their slogan is: "A digital platform for climate resilience and sustainable agriculture" (Agrosmart 2021). This identity, associated with successful marketing strategies were and are important in accessing investments. "The whole world is looking at these problems. This has attracted attention and today we are considered experts in digital agriculture. In addition, we are focused on sustainability and believe that it is possible to create a profitable business, while generating a positive impact both on the environment and on people's lives." (Itaú Mulher Empreendedora 2016)

From the start, the company has had a strong marketing strategy and is very present in the media and on digital platforms such as Facebook, YouTube and its own website. The company frequently participates in webinars and online events (especially during the pandemic) and gave lectures at universities before the pandemic.

Actions and actors

The main actors are the founding partners of Agrosmart, who turned the idea into a product. The CEO, Mariana Vasconcelos, is Agrosmart's main representative in the media and at events, leading the communication of the company's vision and mission in the search for new partnerships and market access. She has a solid entrepreneurial approach that motivates the team and attracts investors. Initial investor and accelerator companies also had an essential role: SP Ventures and accelerator companies Baita and Thrive-funded Agrosmart in its initial (seed) stage have a share in the profits and probably in business decision-making. The series A investors (InovaBRA Fund, Positivo and a large US family that owns farmland in South America) have a share in the profits and take part in decision-making (Brazil Journal 2019). Also, research institutions (universities and Embrapa) established partnerships and public institutions (São Paulo Research Foundation [FAPESP]; and the Funding Authority for Studies and Projects [FINEP]) also participated in funding for research and business.

Finally, the farmers, as early adopters, were important in developing the innovation for the initial demonstration of results and adjustments, taking on greater risk and thus providing the opportunity for testing (in pilot projects) and generating feedback, which is essential for improving the monitoring system and the platform's usability (Sato 2021). Agrosmart currently has an (unofficial) committee of test customers for each product, enabling weekly contact with farmers (Sato 2021). The farmers' motivation for taking part in improving solutions is in customizing the service to their needs.

Developing and scaling up the digital irrigation monitoring innovation coincides with the development of an agtech ecosystem in Brazil. In the last 7 years, there have been consistent signs of growth for such companies, both because it is a highly active risk environment within the country and because of the strong appetite for technological integration by major players in agribusiness (Dias et al. 2019). This was the context for the emergence of Agrosmart.

Outcomes

There are no general data available that enable us to specify the technology's impact and its evolution over time. Recent success stories published by Agrosmart report a 60% reduction in water use and a 30-40% reduction in energy used in the crop irrigation process, in addition to a 20% increase in productivity. The impact is quite varied among users and depends a lot on the farmers' profiles.

According to the company's website (Agrosmart 2021), over 5 years, the Agrosmart Aqua innovation avoided: 41.12 billion liters of water wasted in irrigation; the emission of 11,700 tons of greenhouse gases (CO_2eq); the consumption of 162,000 megawatts of electricity.

According to interviewees, the improvement of the Agrosmart Aqua product and its integration with other products developed by the company has increased the benefits. The most obvious result reported was the efficiency of the monitoring operation, with automatic data collection and data processing by the algorithm, in addition to the advantage of enabling remote monitoring, which facilitates management, since the farmers often are not physically present on farm. A report by a coffee farmer illustrates the efficiency of the operation: Reduced data collection time (from 3 or 4 times a day to about 5 minutes viewing the platform), significantly reducing decision-making time in the field (Agrosmart 2021). Another success story published by the company is the Xavante Farm, a 1,200 ha property that used Agrosmart Aqua to monitor soybeans in real time with a weather station, a rain gauge and soil sensors, irrigation management and satellite monitoring. These led to 45% savings average in water, energy and labor (Agro Bayer Brasil 2021).

In terms of sustainability for farmers, according to interviewees, return on investment in technology can be offset by the first crops. The average time for the equipment to pay for itself is a year, and from the second or third harvest there is already a return for farmers. In the first year, Agrosmart subsidizes part of the equipment installation costs, increasing the return on investment for the company by facilitating adoption (Brazil Journal 2019).

The environmental impacts of more efficient irrigation are reduced water use in irrigation and reduced use of agrochemicals by reducing losses of those inputs. Therefore, efficient irrigation management directly contributes to Sustainable Development Goal (SDG) 6 regarding the sustainable use of water; indirectly to SDG 13, as it enables establishing climate resilience; indirectly to SDG 12 as it generates more sustainable supply chains; and indirectly to SDG 2 by fostering sustainable intensification of agriculture. Although there is evidence that higher efficiency (crop per drop) in some irrigation systems rarely reduces water consumption unless complementary measures are taken (Grafton 2018), in the Brazilian case, it is also important to consider the use of energy, since the Brazilian energy network is based on hydroelectric plants (63.8%) that consume a significant volume of water. Also, it is known that water over-extraction creates water use conflict in Brazil (Multsch et al. 2020).

Economic impacts are related to energy savings, workforce optimization and increased crop productivity. Use of irrigation at the right time generates an increase in production using the same area, due to the plants' better chemical, physiological and metabolic performance. There are no associated social gains, except for farmers' time-saving in data collection and decision-making. The technological package is more accessible for medium and large farmers, strengthening a trend seen in Brazil to exclude less-capitalized farmers from 4.0 agriculture, as they can only access the technology through an intermediary, such as companies or cooperatives.

As a spin-off, other companies have developed similar products and are also benefiting from this growing market. Additionally, Agrosmart is replicating the logic of digital irrigation monitoring in other products. For example, it has developed a digital field notebook application to assist farmers and also provide data for food companies that are interested in monitoring suppliers and brand positioning.

Analysis

The water crisis (2014-16) in southeastern Brazil required solutions for a more efficient use of water by farmers and companies, creating the right conditions in which to start Agrosmart, which was already using its state-of-the-art technology, the prototype of the Aqua solution. Another aspect of the enabling conditions was the Brazilian agricultural innovation system, with consolidated teaching and research institutions and a public and private funding system.

Figure 11 shows the main determining factors for the innovation development and scaling up process, and context enabling factors.

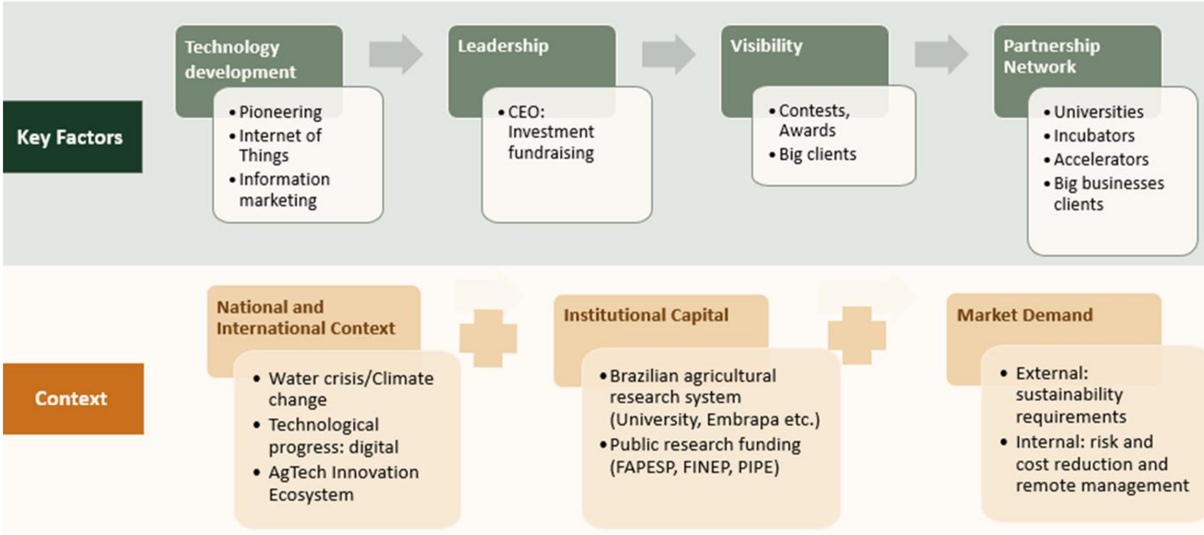

Figure 11. Key factors of the Agrosmart irrigation system.

Source: Agroicone.

In addition to the water crisis in (2014-16), current climate change (increased intensity and frequency of extreme rainfall, more severe droughts and heat waves) continues to drive the demand for solutions for efficient water use and strategies to increase climate resilience. This context leads into other demands: (1) from rural farmers for tools for more efficient water management; (2) from industry for obtaining information on monitoring and controlling supplier production (traceability); and (3) from society in general for sustainability, which puts pressure on industry to seek more sustainable technologies and brand positioning. Productivity and efficiency gains in the operation, cost reduction (in energy terms) and remote monitoring feasibility were and still are motivating factors for adopting irrigation monitoring systems, creating the demand for this type of structural and permanent innovation. Thus, other agtech companies began providing similar technologies and services, replicating the Agrosmart solution.

Agrosmart's innovation meets a constant demand for reducing costs and risks, which are intensified by climate change. In this sense, although there are clear environmental benefits because the tool enables more efficient management of water resources and there are potential benefits from generating and integrating data, it is important to remember that positive environmental impact occurs in traditional large-scale production systems, that is, in an incremental rather than transformative way. Farm size is a determining characteristic of the viability of using the innovation: As a rule, at least 200 ha. Younger customers, the children of those running large farms were the main early adopters of the innovation. They usually have a university degree and are part of a generation that seeks digital solutions. Digital inclusion is a requirement for accessing the technology, which, in addition to farm size, can be a barrier for small farmers.

The strategies chosen by Agrosmart were important factors in gaining scale and have proven to be successful. The company is currently one of the main agtechs in Latin America. Some of the strategies were: (1) taking advantage of the digital agricultural innovation ecosystem in Brazil in the last decade, with the availability of funding (accelerator companies, capital enterprises, public research financing programs and companies); (2) increased number of sales channels through partnerships with other companies; (3) marketing campaigns; (4) participation in investment rounds aimed at start-ups. More recently, Agrosmart started expanding by acquiring other companies (BoosterAgro). The link of the company's identity to sustainability and climate resilience also contributed to the success of its marketing strategy.

Finally, the companies responsible for accelerating Agrosmart and the initial investors were key to launching the product and the company, as well as its addition to an innovation ecosystem. Mentoring from experienced entrepreneurs such as the Baita accelerator and access to training in innovation achieved through awards (e.g., Singularity University, Google) were important for the design of Agrosmart's strategies and for developing products in the initial phase. In turn, partnering with large companies was essential for increasing the company's sales channels and market visibility.

4. Lessons learned and recommendations for innovators and investors

Innovations for a sustainable agriculture provide an opportunity for agricultural producers to increase productivity while better managing natural resources. This helps to ensure long-term viability and reduce the negative environmental impacts of production, such as pollutants and waste. Sustainable agricultural production systems also include adaptations to climate change and mitigate greenhouse gas emissions (OECD n.d.). Due to the complexity, diversity and size of Brazilian agricultural systems, the solutions for scaling innovations for sustainability involve different processes. Innovation managers, investors, stakeholders and governments should consider the contexts of region, country and agricultural sector.

This report addresses three types of innovations – innovation for knowledge transfer and development, social innovation and technology for production, through four case studies – Balde Cheio, P1+2, ILP and ILPF and Agrosmart monitoring irrigation system. These innovations have resulted in social, environmental and economic gains.

Some challenges observed in the case studies include: Difficulties and bureaucracy in terms of accessing credit lines to implement innovation, especially for small farmers; development of key performance indicators aligned with investors objectives; getting long-term funding if the innovation is not aligned with the government agenda; producers' objectives, mainly when the results are observed in the medium or long term.

The learnings presented below are based on case studies in Brazil but can be applied in other countries, providing a pathway for successful SAI, as long as adaptations are made to the relevant country's context.

4.1 Bundling of solutions can improve effectiveness of SAI

The Brazilian cases debunk the idea that it is simple to promote SAI in agriculture through a single innovation/solution, such as good cutting-edge technology, good policies or consolidated institutions. A portfolio of solutions is necessary.

The cases show how the Brazilian innovations have evolved and been adapted to respond to major social, environmental and economic challenges through a systemic/integrative approach that combines consolidated institutions, extension services and end-user participation. Also, for example:

- Balde Cheio: Training and farmer-oriented methodology, networks of partners, training the trainers, continuous improvement to aggregate environmental aspects.
- P1+2: Social technology in the public domain, participation/empowerment of women, partnership between federal government and civil society organized in a network through the private organization ASA and a system for financial management.

- ILP and ILPF: Management of different production systems, a governance structure for partnership – ILPF Network, public policies (ABC Plan), public credit lines (ABC Program).
- IP and ILPF: financing a technological transition involving integrated systems was not a good fit for the credit system, requiring complex adaptations by the banks, so that the whole of the integrated system could be financed

Recommendations

- Operate with governments to design public policies to support the innovation process.
- Governments or private funders should clearly identify the big challenges for research centers in order to stimulate several pieces of technological innovations for SAI goals, and those linked with other political and economic agendas.
- Mission-oriented policy is important for setting the direction from above while allowing and incorporating bottom-up experiences and learnings.
- Working together with banks and governments in order to adapt the credit lines to finance technological transition.

4.2 Leadership (institutional or personal) is important to guarantee the continuity, maturity and visibility/marketing of innovations

Innovation management by consolidated institutions brings credibility, representativeness and mobilization capacity (embeddedness). For example: Embrapa's leadership in Balde Cheio and ILP and ILPF, and ASA's leadership in P1+2.

These programs need consolidated institutions, but also charismatic, persistent, engaged, visionary and strategic leaders. For example, Artur Chinelato and André Novo (Balde Cheio) and Mariana Vasconcelos (Agrosmart).

Although the leadership is personal in the case of Balde Cheio (in most of the program) and in ILP and ILPF (at the beginning), the programs were incorporated into the agenda of organizations such as Embrapa, meaning the personalities were not as important and the program gained scale.

Recommendations

- Map and select local organizations that have a good relationship with local farmers, governments and industries to lead the innovation process.
- Identify good leaders for managing the innovation process.
- Investment in personal capacity building and in programs for forming new leaderships. For example, the entrepreneurship university programs and university incubators. The leader should focus on institutional arrangements and the incorporation of innovation into the institutional agenda, as well as preparing other people to take on roles within the innovation.

4.3 Partnerships are essential for long-term sustainability and scaling up

The innovation results and benefits should be aligned with organizational goals: Decarbonization, social inclusion, improvements in production and income. For example: The partnership with cooperatives, milk industries and municipal governments in Balde Cheio; the public–private partnership in ILP and ILPF; the industries' and municipalities' social goals in P1+2.

The partnerships are important for organizations to complement their skills, working together to achieve the same goal. For example: In P1+2 the partnership with civil society, federal government and municipalities to solve the drought and poverty in semiarid region; the public–private partnership formed the ILPF Network to implement and scale ILP and ILPF; the partnership with cooperatives, industries and technical assistance organizations to improve milk production and its competitiveness, reducing the costs and increasing the yield, profitability and sustainability of production; the Agrosmart partnership with public university incubators was important for starting up the business, and the partnership with private companies was important for testing and improving the technology.

Recommendations

- Include organizations along the value chain, from farmers to the consumer market (industries).
- Create a specific governance structure to manage the innovation. Governance also formalizes and facilitates the partnerships (e.g., committees, legal organizations (ILPF Network), associations, etc.).

4.4 The national and international contexts play a significant role in demand for innovation

In order to gain scale and sell the innovation, it should be connected to the market context and with the government agenda. In the example of ILPF: Brazilian commitment in United Nations Framework Convention on Climate Change (UNFCCC) and ABC Plan were important for scaling up ILP and ILPF; for the Agrosmart irrigation system, the market demand for sustainable practices, such as reduced water consumption, was an important vector to corporate demand; in Balde Cheio, the more efficient production and sustainable practices were and are important to business sustainability; in P1+2 the historic cycle of drought and poverty was the driver for the program.

Recommendations

- Observe how innovations can match political or economic windows of opportunity.
- Investment in tools to measure and monitor the innovation results, as well as good accountability systems and traceability. This is useful for demonstrating the benefits and generate demand. For example, development of a recognized carbon emission methodology is necessary to demonstrate potential effects on climate change mitigation.

4.5 Continuous and good-quality extension services are essential to any initiative in SAI, especially if it involves small farmers

A well set up extension service that is capacity building is important for implementing and disseminating the innovation. Extension services can be more efficient if structured to the regional scale to meet different regional needs: Financing, management, technical and research. For example, in Balde Cheio, the technical assistance is adapted to the regional conditions, producer needs for financing, land management, content and technical assistance. This is possible because there is a governance structure in a national organization (Embrapa), regional organizations (cooperatives, SENAR, agricultural federations, etc.) and local organizations (local technicians).

For example: In ILP and ILPF, the extension services were a bottleneck for adoption and credit access; P1+2 had more impact on farmers who received longer extension services; Balde Cheio shows that extension services should be farmer-oriented and continuous.

Recommendations

- Extension services can be more efficient if structured at regional scales to meet different regional needs: financing, management, technical and research.
- Use the training-the-trainer approach to achieve significant scale gains, especially with technicians from cooperatives and farm associations, along with the technicians of public organizations.
- Investment in training platforms, such as distance e-learning courses combined with a simple platform such as WhatsApp to facilitate access for small farmers.
  Consider the extension service as part of the cost of innovation development.

4.6 End-user participation is essential for continuous innovation improvement and adjustment

A collaborative approach between end users and researchers is very important for identifying problems and for developing and testing solutions. Implementing pilot units (early adopters) to test ILP and ILPF and the Agrosmart irrigation system was important for continuous feedback and improvements. In Balde Cheio, the farmer-oriented approach and the continuous dialogue among supervisors, extension agents and farmers were the basis of the program. In P1+2 the selection of technology packages already tested/used by local farmers was important for farmer engagement.

Recommendations

- Identify organizations or consortia with access to farmers (to engage them and develop learning units).
- Create/establish dialogue channels and participatory mechanisms (e.g., co-creation labs and learning units).
- Support the creation and development of institutional capacity of farmers' organizations (cooperatives and associations) or support innovation mechanisms in existing organizations that have good local knowledge.
- Understand the end-user context to adjust and improve innovations.

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Annex 1: Common analytical framework

1. Description of the case

1. Construct a timeline of key events, such as innovation development, piloting, early scaling and ongoing growth.
2. What type of innovation is it? Technology, policy/regulation, social institutions, financing, other services?
3. The innovation was a solution to what problem?
4. What are the key components of the innovation? Core innovation? Complementary innovations? Delivery model?
5. What was the business or funding model? When and how did it become sustainable?
6. How was the process of scaling funded?
7. How was the innovation funded for users?
8. How was the innovation developed and tested?
9. Where was the innovation introduced and scaled? How did this evolve? Why evolution?
10. Who were the users of the innovation (demographics)? How did this evolve? Why evolution?
11. How did the context (where and who) affect the design and adaptation of the innovation? Scaling strategy?
12. What was the scaling pathway and strategy? Public, private, civil society, PPP, some other combination?
13. To the extent scaling was a partnership or collaboration, how was coordination managed?

2. Outcomes

1. What changes, outcomes or impact did the innovation produce at scale? Did impact change over time? At scale?
2. What evidence is there on outcomes at scale? Effects on different SAI objectives (environmental, social, human, productivity, profitability)?
3. What were the costs and benefits?
4. Who were the winners and losers of innovation?
5. What happened to different groups?
6. Any compensation or mitigation measures?
7. Any spin-offs or unexpected benefits?
8. As best you can, is the innovation sustainable for users? For any organization involved in the production, delivery, funding, etc. (if relevant)?

3. Actions and actors

1. Who were the key players and their roles through time?
2. What were the relevant characteristics of these players in terms of leadership, skills, competencies, resources or organizational culture?
3. Who initiated and led the innovation process, and their motivation? The scaling process, and their motivation?

4. What challenges or opportunities arose, and how was the innovation and/or scaling strategy adapted in response?
5. How was the innovation process designed? Was this a deliberate strategy, make it up as you go along, or a mix?
6. How was the scaling strategy designed and developed? Was this a deliberate strategy, make it up as you go along, or a mix?
7. Were different phases of innovation and scaling led by different groups? Why? How did the handover take place?
8. What partners were brought in, why, and how?
9. What roles did they play (or contribute) in innovation and scaling?
10. Why were they willing to play these roles? How were they persuaded?
11. How were intended users involved in the innovation and scaling process? At what points? What mechanisms?
12. Did demand exist in advance, or was it developed or created? If the latter, how was demand generated?
13. Did the scaling process include other complementary systems changes such as policy, laws, regulations, strengthening parts of the value chain, market system or public sector organizations, e.g. capacity building?

4. Analysis

In your opinion, justified by evidence, what role did the following factors play in explaining the outcome at scale?

1. The innovation processes.
2. Innovation characteristics, including business/delivery/funding models.
3. Relevance to demand, needs and priorities of users, other stakeholders.
4. Characteristics of the users or places, e.g. infrastructure, education.
5. Context, e.g. policy enabling environment, public sector organizations and capacity, value chain or market system actors.
6. Choice of scaling pathway and strategy.
7. Specific scaling activities, e.g. evidence generation, advocacy/marketing, community engagement, pricing, risk mitigation, use of champions.
8. Characteristics of organizations/actors leading or driving the innovation and scaling process.
9. Characteristics of partnerships and the organizations/actors that served as partners in the innovation and scaling process.

Annex 2: Interviews

Case study		Name	Institution	Position	Date
Balde Cheio		André Monteiro Novo	Embrapa Pecuária Sudeste (Empresa Brasileira de Pesquisa Agropecuária)	Balde Cheio – Project Coordinator	August 4, 2021
		Maurício Salles	SENAR – Rio de Janeiro	Coordinator of Technical and Management Assistance at SENAR Rio de Janeiro	August 13, 2021
		Ana Paula Roque	CATI	Zootechnician at CATI	August 13, 2021
		Rodrigo Ferreira	–	Farmer	August 12, 2021
		José Geraldo	–	Farmer	August 24, 2021
P1+2		Arnoldo Anacleto de Campos	MDS	National Secretary of Food and Nutrition Security (2013-16)	August 6, 2021
		Lilian Rahal	MDS	Assistant Secretary of the Department of Food and Nutrition Security (2011-19)	August 11, 2021
		Luzia Teixeira Brito	Embrapa Semiárido	Retired	August 25, 2021
		Alexandre Pires	ASA	Coordinator	August 25, 2021

Case study		Name	Institution	Position	Date
ILP and ILPF		Geraldo Martha Junior	Embrapa Informática Agropecuária	Researcher at Embrapa Informática Agropecuária	August 6, 2021
		Lourival Vilela	Embrapa Cerrados	Researcher at Embrapa Cerrados	August 11, 2021
		Renato de Aragão Ribeiro Rodrigues	Embrapa Solos/Rede ILPF	Researcher at Embrapa Solos and current president of Rede ILPF	August 16, 2021
		Marize Porto	Fazenda Santa Brígida	Farmer	August 23, 2021
Agrosmart		Marcus Sato	Agrosmart	Head of Technical Sales	August 5, 2021 August 9, 2021
		Guilherme Raucci	Agrosmart	Head of Business Development & Sustainability LATAM	August 17, 2021
		Marcelo Cocco Urtado	Fazenda Três Meninas	Farmer	August 18, 2021
		Raphael Santana	Cargill	Supervisor of agricultural research	August 23, 2021

Annex 3: Cases against criteria

Case study	Date	At scale	Transformative	Initiators	Type of innovation	Application
1. Balde Cheio	1998	In 2020, 1,626 rural properties were served in 478 municipalities in 21 states by 246 extension agents in training.	Technology and good management reduce rural migration and enabled family farmers to increase their income; obtain productivity gains; and improve management of the environmental impacts of production systems.	Research at research and development institution (Embrapa)	Innovative technological transfer and capacity building in agricultural extension advisory services	Small (mainly), medium and large scale
2. P1+2	2007	By 2021, 207,000 water technologies for food production had been implemented.	Relevant impacts on food security for small producers, as well as strategies for adapting to climate conditions, and scarce resource (water) management.	Civil society organized into networks	Bundle of technologies, public policy and institutional arrangements	Small scale
3. ILP and ILPF	1980	11.5 million ha in 2015	Integrated production system to promote the best use of resources, faster economic return, land optimization and increased carbon uptake; improves soil fertility, water storage and soil cover quality for no-till.	Embrapa	Bundle of technologies	Medium to large scale
4. Agrosmart digital irrigation monitoring system (Aqua)	2014	800,000 ha monitored	Water efficiency	Agtech start-up	Technology	Medium to large scale

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