Title

Motivations and challenges of intrapreneurship in research organizations. The case of Decision Support Systems in agricultural research for development

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Highlights

- **Researchers behind the development of DSS wish to have an impact outside of research**
- **While institutional mechanisms aim to strengthen the impact of research, intrapreneurs remain key players in innovation**
- **Institutional measures to promote innovation and impact do not necessarily provide resources for intrapreneurs**
- **Research institutions should think strategically when deciding whether or not to support the development of a DSS to an advanced level**

Abstract

This article focuses on researchers who are using the outputs of their scientific research to develop decision support systems (DSS) for non-researchers, and thereby are assuming the role of intrapreneurs. We examine the role and motivations of individual researchers in producing these DSS in relation to the main organizational barriers and opportunities presented by their home institution. The study is based on interviews with researchers, computer engineers, and senior-level managers at CIRAD, a French agricultural research for development institute. Our findings reveal that individual motivations are key and often clash with institutional concerns regarding products that fall outside the institution's usual field of expertise. Research institutions should consider carefully the relevance of investing in the development of finalized DSS given the time and effort required from researchers. This study offers a perspective on intrapreneurship processes, highlighting the motivations of researchers to generate impact outside academia and the opportunities and conflicts emerging from the internal realities of research institutions.

Keywords

Academic intrapreneurship, decision support system, TRL

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Abstract and keyword

This article focuses on researchers who are using the outputs of their scientific research to develop decision support systems (DSS) to advanced technology readiness levels. By taking their DSS beyond the published proofs of concept level, they are assuming the role of intrapreneurs. We examine the role and motivations of individual researchers in producing these DSS in relation to the main organizational barriers and opportunities presented by their home institution. The study is based on interviews with researchers, computer engineers, support services staff, and senior-level managers at CIRAD, a French agricultural research for development institute. Our findings reveal that individual motivations are key and often clash with institutional concerns regarding products that fall outside the institution's usual field of expertise. Research institutions should consider carefully the relevance of investing in the development of finalized DSS given the time and effort required from researchers. This study offers a perspective on intrapreneurship processes, highlighting the motivations of researchers to generate impact outside academia and the opportunities and conflicts emerging from the internal realities of research institutions.

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1. Introduction

Public scientific research has to produce knowledge that is accessible to all and can be used to address major societal challenges (Foray et al., 2012). Prompted by societal, economic, and political expectations, research institutions engage in innovation to serve commercial and/or public utility purposes and to generate impact to benefit society (Blundo-Canto et al., 2019; Compagnucci & Spigarelli, 2020; Sengupta & Ray, 2017).

Science-based digital tools, which encapsulate knowledge, are an interesting example of objects that can embody the fulfillment of public research missions. This is illustrated by the development of information technology (IT) from the 1980s onwards, and the availability of this technology in research laboratories (Ensmenger, 2012). IT enables researchers' knowledge to be translated into digitized models that provide a synthetic and explicit representation of processes under study and offers the possibility to explore new questions and configurations (Berry, 2017; Epstein, 2008; Winsberg, 2019). However, the scientific community is often the only user of many models designed and developed by researchers. While some researchers consider publication and prototypes as the end products of a normal research cycle, others view these as simply stepping stones. They seek to respond to the demand, generated by the ever-expanding role of digital tools in society, for knowledge produced by researchers to be translated into usable tools (Owen et al., 2012).

These digital tools can take many forms, such as databases, (geographical) information systems, and decision support systems (DSS). The latter have been developed significantly since the 1980s (Power, 2008) as they represent a potential way for research institutions to respond to societal demands in many areas. Wishing to increase their impact, some researchers engage in the production of finalized digital DSS that non-academic actors can use. This new stage confronts them with a complex and risky process whose success is not guaranteed (Bozeman, 2000). This process is not a conventional one within their institutions, which forces them to pursue an ill-defined path. They thus act as intrapreneurs, "entrepreneurs within an existing [organization]" (Klofsten et al., 2021, p. 2). As described by Blanka (2019, p. 922), intrapreneurs "use the existing resources of the company, operate within organizations, and work within organizations that already have their own policies and bureaucracy". Although DSS have been studied extensively, the intrapreneurial process of their production has received little attention (Compagnucci & Spigarelli, 2020), especially from an individual-level perspective (Blanka, 2019). This article proposes to tackle this gap, using a case study drawn from the field of agricultural research.

Indeed, agricultural research institutes are particularly interesting arenas in which to investigate these issues, for three reasons. First, these organizations have from the outset been entrusted with a mandate for applied and targeted research to promote innovation among farmers and all stakeholders in the agricultural sector (Goulet, 2018). This is even truer for the Agricultural Research for Development (AR4D) organizations, which were created in the early 1970s - notably members of CGIAR[1] - to promote rural development in the Global South. Second, since the mid-2000s these organizations have undertaken particularly proactive institutional initiatives to strengthen and demonstrate the impact of their research on agricultural and rural sectors. These initiatives are part of a common trend among all research organizations, not just

[1] Consultative Group on International Agricultural Research. An international organization founded in 1971 under the sponsorship of the United Nations, whose mission is to coordinate agronomic research programs for the benefit of developing countries.

agricultural ones, to demonstrate the usefulness of public funding for science and technology. For AR4D organizations, this trend has been reinforced by the objective of strengthening their accountability to international development donors, both public and private, who provide a large part of their funding (Renkow & Byerlee, 2010). Third, since the late 2000s, a powerful movement to digitalize agriculture has swept through agricultural research organizations, which see digital technologies as a means to develop more efficient and sustainable production (King et al., 2021). DSS, and more broadly other technologies linked, for example, to precision agriculture or extension and training, are at the heart of these dynamics.

In light of this context, we could hypothesize that researcher-intrapreneurs in agricultural research institutes working on DSS are in perfect alignment with the policies of their home institutions. In reality, however, little is known about these researchers' motivations and practices, or how these fit their organizations' strategies. Science and Technology Studies (STS) literature is full of accounts of how researchers have mobilized against the choices of their institutions, for example against certain technological choices such as the development of Genetically Modified Organisms (GMOs) (Bonneuil, 2006), or as a protest against the military applications of public research (Moore, 2008). The development of DSS by researcher-intrapreneurs in agricultural research would not, however, be expected to be among these cases. In this article, we propose to put this hypothesis of alignment to the test, using the case of researchers involved in the development of DSS within an AR4D organization. We will address the following question: What are the roles and motivations of individual researchers in producing DSS, a process that is beyond their actual scope of work in the context of research-based institutions? What are the main organizational barriers and opportunities presented by their home institution during this process? We conducted a theory-building qualitative exploratory study to better understand these dynamics.

This article is based on a qualitative survey conducted within the public French International Cooperation Centre in Agricultural Research for Development, CIRAD has been historically engaged in action research in tropical agriculture, and the authors of the present article are CIRAD staff members. Given the question under scrutiny, we targeted researchers working in various domains who are developing DSS, as well as some of their collaborators. The latter include computer engineers at CIRAD involved in the development of these tools who may assist in their projects, members of the technology transfer office team who provide official support to increase the readiness of technologies, and managers with insight into the institution's point of view who have a strategic vision of projects to be supported.

The article is structured as follows. We start with a review of the literature, examining: i) intrapreneurship within research organizations, ii) the rising emphasis on impact in the strategies of agricultural research institutions, and iii) the growing influence of digital technologies in the agricultural research agenda. The methods section then provides detailed insights into the Technology Readiness Level (TRL) measure, the research design, and the data collection procedures used. The results section presents findings from the analysis, considering both the researchers' and the institution's perspectives, supplemented by results on the challenges specific to DSS finalization. We end with a discussion and conclusion section that interprets the results and their implications for the institution's strategies.

2. Literature review

2.1. Intrapreneurship, research organizations, and societal landscape

For over two decades, many universities and research organizations have been on a trajectory that has transformed them into quasi-firms (Etzkowitz, 2003). This has involved identifying potential economic benefits and gains from research conducted by researchers (Siegel & Wright, 2015a), and, in doing so, inviting researchers to behave as intrapreneurs. Many works on entrepreneurship in academic spaces have reported the rise of this economic dimension (Siegel & Wright, 2015b). The institutional policies of this race for the economic valorization of research and innovation have led to the development of various mechanisms encouraging the meeting of science and industry, such as technology transfer offices (Chapple et al., 2005), incubators and other technology parks (Link & Scott, 2011).

Etzkowitz (2013) describes the process by which a university adopts an entrepreneurial orientation as having four stages: (i) establish priorities, (ii) acquire financial resources, (iii) involve academics in an active role, and (iv) engage with stakeholders. Even though the process does need to be sequential, a key point is recognizing that a specific domain is a priority. Horner et al. (2019, p. 1299) note the importance for universities "to make appropriate choices about strategic priorities with regards to the type of technology transfer and the specific scientific fields". Furthermore, Giuri et al. (2019) observe that changes in priorities need to be tailored to an institution's identity, culture, and ecosystem. Specific contexts, such as pressure from funding institutions, can drive specific developments and mobilization of resources following the path identified by Etzkowitz (2013). While it may be possible to adapt to specific demands, a strategic and processed approach requires further thinking by the institution. In many cases, researcher-intrapreneurs are mostly self-involved, self-engaged with stakeholders, and seek funds on their own. As Rigtering and Weitzel (2013, p. 342) observe in non-academic contexts, "the decision to opt for intrapreneurship remains an individual and personal decision". Moreover, the propensity of intrapreneurs to undertake a transformation of their organization remains fairly low, their approach remaining above all "incremental and opportunistic rather than transformation or confrontational" (Heinze and Weber, 2016, p. 13-14.)

Kyvik (2013) lists six major roles for researchers: networking, collaborating, managing research, doing research, publishing research, and evaluating research. Acting as an intrapreneur and producing outputs directly usable outside of research thus is not considered a central role for researchers. Limited information is available on these individual logics and how they interact with institutional logics (Burkholder & Hulsink, 2022), and on the motivations of academic intrapreneurs (Hernández-Perlines et al., 2022). However, some elements are already known (Balven et al., 2018), particularly regarding the demographic components and trajectories of intrapreneurial researchers, as well as the diversity of their motivations (Perkmann et al., 2021). D'Este & Perkmann (2011) identify four main motivations for researchers to collaborate with industry: commercialization, learning, funding, and in-kind resources. Intrinsic motivations, namely satisfaction in conducting the activity and the self-esteem of researchers, drive development, as noted by Escobar et al (2017). Self-esteem is the researcher's desire to see his/her work be useful and to have a positive societal impact in terms of public value and economic development beyond research (Bicknell et al., 2010). Some researchers also have extrinsic motivations, such as reputation with actors outside or inside their home institution. This source of motivation seems to remain limited within the staff of most institutions, as many researchers and head members stick to the six roles of researchers identified by Kyvik (2013).

The willingness of research institutions to encourage researchers to engage in intrapreneurial activities is crucial because they can be essential components of the institutional journey toward entrepreneurship (Henry and Lahikainen, 2024). The development of intrapreneurial capabilities among academics (but also among students (Ben Youssef et al., 2021)) is, therefore, an essential lever in this strategy. It is these capabilities that enable organizations to react quickly and innovate in the face of external change (Klofsten et al., 2021). MOOCs in the specific context of the digital economy (Guerrero et al., 2021), but also incubators developed within universities (Shekhar et al., 2023), are particularly relevant environments to develop capabilities and translate them into organizational learning. Collaboration with non-academic actors to achieve societal impacts, even when direct economic benefits are not immediate, also is essential. The choices and strategies of organizations depend moreover on the political landscape in which they operate, and the degree to which these strategies are aligned with the institutional environments (Eesley et al., 2016). At national and regional levels, funding policies for the academic sector over the past two decades have aimed to encourage scientific and technical activities capable of bringing about transformative change in societies (Weber & Rohracher, 2012). This quest for operationalization has involved defining grand challenges (Foray et al., 2012; Kallerud et al., 2013; Kuhlmann & Rip, 2018) around which scientific actors have to mobilize and demonstrate their capacity to generate solutions for the future. The choice of these challenges, and more specifically the terms used to identify them, aim to highlight "umbrella" concepts (Rip & Voß, 2013) that address current social issues and engage diverse disciplinary fields (Kuhlmann & Rip, 2018). Thus, research institutions increasingly consider societal impact as a central mission within a regime of strategic science based on the dual alignment of global competition and local relevance (Rip, 2002, 2004). Although defining basic research can be highly challenging (Calvert, 2006), this mission is central for institutes focused on applied research and that address crucial challenges such as sustainable development (Wakkee et al., 2019).

The importance of these major challenges and the operationalization of research are additional criteria facing researchers operating in an increasingly competitive funding environment. In a way, this reinforces the significance of researchers' entrepreneurship, going beyond a solely profit-focused approach to academic work. Studies on the impact of research, considering a plurality of externalities resulting from scientists' work, whether they are economic, environmental, social, symbolic, or other (Bornmann, 2013), shed light on further understanding this evolution. The field of agricultural research, particularly research for development, is particularly suitable for grasping the potential convergence between researchers' individual entrepreneurial strategies and the institutional policies of scientific organizations.

2.2. Agricultural Research and Impact: building an organizational culture

The concern regarding the impact of research generally refers to the influence and benefits generated by research organizations beyond academia, mainly in socio-economic terms (Bornmann, 2012; Penfield et al., 2014). The consideration of this impact, its qualification, and quantification, has led to a series of reflections and studies on how to measure impact beyond purely economic effects. The challenge is complex, as the relationship between research and societal impact is not linear, with indirect repercussions and often unpredictable timelines (Reed et al., 2021). The question of how to assess the systemic effects of research has thus emerged on the agendas of research organizations and scientists working on measuring research impact (Amanatidou et al., 2014; Joly & Matt, 2022).

Agricultural research organizations have been engaged in goal-oriented and applied research since their inception. However, since the early 2000s, they have been playing a pioneering role in developing policies and institutional mechanisms to strengthen and demonstrate the impact of their work. Wright has shown that US donor requirements gradually led CGIAR research centers to focus on major challenges such as fighting world hunger and promoting global food security (Wright, 2012). This connection to a major challenge is helping to drive the strengthening of requirements to demonstrate the impact of research on donors and public policymakers (Joly & Matt, 2022). Numerous studies have been conducted on the development of evaluation methods for the multiple dimensions of agricultural research impact (Joly et al., 2015), particularly to assess the contribution of agricultural research to the competitiveness of the agricultural sector (Gaunand et al., 2015).

The field of AR4D and its institutions also have been a venue for reflections on understanding the impact of research on societies in the Global South, with their constraints and specificities (Faure et al., 2020). This is particularly true for CGIAR, where a culture inherited from the hard sciences, seeking direct attributions and cost/benefit effects, prevailed for a long time (Horton, 1998), but where systemic and complex thinking has gradually gained ground (Douthwaite et al., 2003). The challenge of institutional learning, aiming to go beyond technology transfer approaches and consider forms of co-construction of innovations, has thus emerged (Watts et al., 2007). On this topic, recent work on CGIAR has demonstrated the difficulty of evaluating the impact of researchers' work in terms of both scientific contributions and development impacts, with the risk of only considering the latter without respecting the specific timelines of scientific research (Leeuwis et al., 2018).

The issue of measurement and methodologies is an essential facet of the problem faced by research organizations, agricultural, and others. However, another fundamental component is the modalities through which organizations can encourage research that leads to impact. On this front, the problems raised in the literature closely converge with those posed by entrepreneurship in research and the modalities to encourage it. Jacob et al. (2003) posit that transforming a university to be more entrepreneurial requires changing its organizational structure and adapting its culture and mission. The focus has been on creating a culture of impact within research organizations, and the literature on AR4D provides particularly relevant observations. Scholars have highlighted the importance of developing new professionalism for CGIAR centers, based notably on direct engagement with rural communities (Douthwaite & Hoffecker, 2017), research "in" development rather than "for" development (Coe et al., 2014), and, more generally, the closer integration of research with all actors in agricultural innovation systems (Thornton et al., 2017). While investigating the foundations for building a culture of impact within CIRAD, Blundo-Canto et al. (2019) identify the challenge of constructing *ex-ante*[2] impact assessment practices, rather than just *ex-post*, to encourage researchers to consider the impact of their research on societies from the outset. They identify three elements constituting a culture of impact: (i) understanding the links between research activities and the changes they induce in societies, notably by considering the multiple roles of researchers beyond publications; (ii) equipping researchers to accompany positive changes resulting from their work, and mitigate possible negative effects, by providing them with appropriate intellectual frameworks and methods; and (iii) developing strategies to promote the percolation of a culture at different levels of an organization, among researchers, managers, and other employees or partners of the organization. In this sense, the culture of impact aims to enrich researchers' working methods to

[2] In 2023, 400 researchers and technicians from CIRAD (out of approximately 1700 employees) had undergone in-house training on ex ante evaluation of research impacts.

enhance the impact of their work and create connections between them and the rest of their organization. This approach challenges the vision of intrapreneurial researchers as innovation champions (Greene et al., 1999) operating alone or almost alone to reach non-researchers.

As we will see in our results, the development of DSS within CIRAD allows us to refine our understanding of this tension between researchers and their organizations. But before that, let us conclude this literature review by examining how digital technologies in agriculture - including DSS - have occupied a prominent place on the agricultural research agenda for the past decade.

2.3. The rise of digital technologies on the agricultural research agenda

Digital technology holds a special place in agricultural research. Digital technology and information communication tools form a general-purpose technology (Berry, 2008), often referred to as the digital revolution. The development of these tools is supported by major international institutions with the promise that digital technology will enable greater food production and ensure food security for humans (Lajoie-O'Malley et al., 2020). CGIAR states that "digital innovations can enable an unprecedented transformation of food, land, and water systems for greater climate resilience and sustainability."[3] Digital technology can be applied in various fields such as precision agriculture (Shannon et al., 2020) and plant improvement processes using sophisticated machines, as well as in non-field settings for agricultural advisory services (Steinke et al., 2021), weather forecasting (Kendall & Dearden, 2020) and plant recognition (Heimstädt, 2023a) apps, and market information and access. As demonstrated by the Digital Agri Hub[4] managed by FAO, the range of tools implemented is vast, with promises, successes, and numerous failures (Aker et al., 2016). While private entities currently are investing heavily in this sector (Birner et al., 2021), researchers have long been involved.

Work on DSS, which are designed to support the actions and decisions of non-researchers, is closely aligned with the logic of applied research, and received investments early on. These tools range from "interactive computer-based systems, which help decision-makers utilize data and models to solve unstructured problems" to "any system that makes some contribution to decision-making" (Sprague, 1980, p. 1□2). DSS are developed in various domains, such as agriculture (Le Gal et al., 2011), the environment (Matthies et al., 2007), natural risk management (Newman et al., 2017), oceans (Pınarbaşı et al., 2017), and territories (Zasada et al., 2017). DSS are extensions of models developed within the normal framework of research work which rely on the computational capabilities of various digital tools. These models, published as articles, can represent the culmination of research, corresponding to the classical role of researchers described by Kyvik (2013).

In many cases, a mismatch appears between the design of DSS by researchers and their use by non-researchers. This phenomenon has been observed since the 1980s (Sharda et al., 1988) and is still relevant (Masiero, 2016; Steinke et al., 2022). Based on this observation, extensive literature emphasizes the need to better take into account the needs, policy context, and decision-making context of target audiences in the design and development of DSS, both *ex-ante* and *in itinere* (Bolman et al., 2018). In this context, researchers increasingly base their research on interactions in open environments such as living labs and innovation ecosystems (Granstrand & Holgersson, 2020; Hossain et al., 2019). This line of research is often associated with the practice of digital

[3] https://www.cgiar.org/initiative/digital-innovation/

[4] https://digitalagrihub.org/

tool development based on participatory design (Jakku & Thorburn, 2010; Smith et al., 2017; Steinke et al., 2022), user-centered design (Rose et al., 2017), co-design (Kendall & Dearden, 2020), and co-innovation (Berthet et al., 2018) methods. In such environments and methodologies, researchers are expected to interact more with other types of actors and increase the probability of designing useful tools (Steinke et al., 2022). These modeling phases can also result in scientific articles, strengthening the science-society link while ensuring extrinsic esteem through professional recognition. However, these efforts can be insufficient, as adaptations to users do not guarantee longevity, the success of the business model, or that the challenges of maintenance and storage are met.

Going beyond this stage, and pushing tool development to a complete transfer to an external audience, engages researchers in a complex and risky process with no guarantee of success (Bozeman, 2000). NASA introduced the concept of "Technology Readiness Levels" (TRLs) as a discipline-independent measure to allow more effective assessments of, and communication about, the maturity of new technologies (Mankins, 1995, 2009) (Appendix A). The European Space Agency (2013) has adapted the measure for software. The levels range from 1, for basic research, to 9, for fully tested technology in real settings. Research typically stops at TRL 3 with proofs of concept, models, and published results, at which point industry takes over. Under the framework of our study, we are interested in agricultural research intrapreneurs who work on these tools to bring them beyond TRL3.

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The research question we seek to answer in this article focuses on the motivations of researcher-intrapreneurs developing DSS, and on the interfaces between these motivations and the mechanisms and actors of their institutional environment. This literature review confirms the knowledge gap surrounding the activity of researcher-intrapreneurs in the development of DSS, and more generally in digital technologies. It also highlights the need to clarify the relationship between researchers and their institutional environment in relation to these technologies. The case of digital technologies, which constitute one of the major technological promises within the agricultural research ecosystem, is particularly relevant for apprehending the modalities of this commitment by researchers and their supposed alignment with their institutional environment.

3. The case studied: DSS development at CIRAD

CIRAD is a French public agricultural research for development institute working on agricultural and food systems in the Global South. One of its missions is to design and propose solutions to the problems of various actors, either by disseminating them directly or by co-designing them locally. It conducts research through partnerships with scientific and non-scientific organizations from around the world. It employs 800 researchers from a variety of disciplines, ranging from biology to the humanities and agricultural sciences, who are grouped into three research departments that are divided into 33 research units. The computer engineers employed by CIRAD focus on two main activities: providing support to researchers, including the design and co-production of finalized solutions, and developing and maintaining the in-house information system.

In line with its mission as an applied research institute, CIRAD currently showcases "innovation and impact" (Blundo-Canto et al., 2019) as driving forces for sustainable development. These concepts form the core of its strategy, which focuses on capacity building, the production of useful knowledge, and capitalization by companies. Those concepts are operationalized through internal technology transfer offices and broader local and national technology transfer acceleration companies. One of its commitments is to "ensure that agriculture in the South benefits from tools and services related to digital transitions and ongoing technological developments in the field of food and non-food production and processing" (Cirad, 2017). At the same time, CIRAD is developing methodologies for supporting actors and action research in partnership (Faure et al., 2010; Le Page et al., 2012). Its relations with local societies in tropical areas are thus a central concern in its activities. Moreover, CIRAD is a public industrial and commercial enterprise (a status known by its French acronym, EPIC) of which only two-thirds of its budget is covered by a grant from the French government. CIRAD is therefore obliged to finance the remainder by other means via research projects, providing consultancy services to public and private operators, and the sale of products and services, which may include any software developed in-house.

Due to its characteristics (applied research and partial coverage of its budget by a public subsidy), CIRAD represents a relevant context for the study of the intrapreneurship role embodied by researchers who would like to strengthen the practical applications of their research.

4. Material and methods

4.1. Methodological background

We used a qualitative theory-building approach based on interviews and grey literature (De Massis & Kotlar, 2014; Eisenhardt & Graebner, 2007). The research question addressed led us to analyze the design and journey towards the finalization of DSS as software, web applications, or other in the particular situations where researchers have assumed the role of intrapreneurs.

Given the subject under study, the analysis focused on four types of actors within the research institution. First, researchers who model, design prototypes, and decide to transform them into software. Second, computer engineers who accompany them in this process by providing them with their computer skills. Third, top managers who define collective strategies and run research departments. Fourth, the valorization team who contribute to the organization of the institution in terms of legal and commercial support services, and the provision of transfer services such as the institution's website and links with external actors. Since we adopted a perspective from within the institution, we did not meet the users and actors targeted by the tools studied, related institutions such as donors and partner research institutes, nor software publishers, but they were mentioned in our analysis when cited by the interviewees. The analysis focused on the motivations of researchers, the resources they mobilized, and if and how their approach fitted with their institution and its impact-oriented policy.

4.2. Data collection and analysis

The main data was collected between 2020 and 2023. The selected researchers (n= 19) responsible for DSS development were identified through a presurvey conducted within the institution and the personal inside knowledge of the authors. The minimum level of DSS development required was TRL4 (Appendix A). The researchers were invited to participate through direct contact using institutional means such as emails, telephone, and in-person communication.

We designed an online survey using a methodological approach that incorporated the TRL and Likert scales, along with systematic open boxes for comments. The survey questions were developed specifically for this study.

We completed this survey with semi-structured interviews of researchers (n=9), computer scientists (n=2), managers (n=8), and members of the transfer and valorization team (n =4). The researchers interviewed were selected on a voluntary basis from the original list of researchers identified (Table 1). They came from various disciplinary backgrounds, such as agronomy, economics, remote sensing, applied math, computer science, and modeling. They were hired at CIRAD between 1986 and 2016. We did not take into account their disciplinary background in our analysis given the small sample size, but we took their seniority into account since it helped understand variations in how much digital tools were part of their scientific approach. The individuals from the transfer department were purposefully selected to include the head of the department, the valorization team, and the person responsible for the valorization of genetic and plant resources. The members of management selected for interviews were the heads of the three departments within the institution, as well as the Vice President.

Table 1: Demographics of interviewees

Researcher	Recruitment date	Discipline of expertise	Computer languages mastered	Computing skills*
A	1986	Early warning system, climate change, modeling	Pascal, Delphi	5
B	1986	Farm agronomy	None	1
C	1987	Agro-socio-economics, microeconomics, prospective, modeling	None	1
D	1992	Economics	None	1
E	1993	Applied math, AI, remote sensing, crop ecophysiology, modeling	Matlab, R, VB	4
F	2004	Remote sensing, spatial information modeling	Ocelet, R, python	4
G	2010	Agronomy, modeling	R	2
H	2013	Data science, text mining	Python / Perl	4
I	2016	Agronomy, remote sensing, user-centered design, fruits	None	1

*self evaluation (1=none, 5= very skilled)

Whenever possible, the interviews were conducted face-to-face; when this was not the case, they were conducted through an in-house videoconference system. Each interview followed a predefined set of questions to ensure consistency, lasted between 45 minutes to 1 hour, and was transcribed.

The data collected underwent a thematic analysis, and the most significant verbatim extracts were classified according to the themes specific to each type of actor. For the researchers, we aimed to explore their perceived roles and motivations that led them to develop their DSS beyond TRL3, their personal trajectories regarding DSS development, their skills, and the internal and external resources they mobilized for their project. We asked computer scientists the type of projects they usually work on, their relationship with researchers, and their views and participation on DSS TRL increase activity. The interviews with the upper management aimed to understand their knowledge of the DSS landscape within the institution and their views regarding the specific activity of DSS TRL increase by researchers. The themes of interest for the valorization team were the team's main strategy regarding project selection and the support provided for DSS, as well as the procedure for classic outputs such as vitroplants and genetic resources.

To ensure the trustworthiness and validity of the analysis, our findings were shared with the participants through an initial version of this paper. Some participants provided feedback, which was considered during the analysis process.

5. Results

In this section, we begin with an examination of the researcher-intrapreneurs' perspective, including their motivations and contextual perceptions. We then analyze the institutional environment to reveal the impact of managers, support services, and computer engineers on elevating TRLs. These findings are used to explain how researcher-intrapreneurs navigate the process of increasing the TRL of their DSS by utilizing their skills and resources while encountering various IT obstacles.

5.1. The researcher's point of view

5.1.1. The researcher-intrapreneur: individual motivations and perception of the context

A key driver behind the development of a DSS is the researcher-intrapreneur's interest in the issues addressed by the tool, its formal modeling, and its evolution into a tool that could be used by non-researchers. First, like any modeling exercise, the tool appears to be a means to develop research on a specific topic, to formalize questions, and to progress in their thinking. As expressed by a senior researcher, the developer of a DSS that has undergone numerous evolutions: "*The development of the software has enabled a great deal of cognitive work to be carried out, enabling us to move away from a tacit practice towards an explicit one*". Some software are described as being the common thread and result from several years of research on a given theme.

Beyond these considerations, which are valid for any significant modeling activity, the rise in TRL is mostly based on the personal interest of the researcher in seeing the product of his or her work emerge from a scientific sphere to reach non-scientific users. This individual motivation may be expressed as early as the initial phase of the prototype co-design process, with the establishment of interactions with stakeholders representing the future users. Through their questions, practices, and requests, these stakeholders help encourage researchers to invest further in the problems studied and the development of software that are more operational than "simple" publishable prototypes. Moreover, the involvement of field actors forces researchers to define clearly the terms of their involvement. This can range from responding to specific and contextualized requests to producing a tool that can be upscaled and function in a variety of contexts while remaining focused on the initial objective and topic. It is through these interactions between researchers and field stakeholders, in very heterogeneous contexts, that the tools progress in their development and genericity with the integration of new functionalities. For instance, SARRA, a "Regional Agroclimatological Risk Analysis System" for the Sahelian region, underwent multiple evolutions thanks to interactions with the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) and various regional actors between 1986 and the present[5]. Initially based on classic crop models, the model branched out, including water and carbon, and coupling with agent-based models. The system was mainly developed by a single researcher who occasionally collaborated with other CIRAD researchers. Interactions with external actors led to the co-definition of research subjects and the obtention of funding. Despite a strong and supportive demand environment, internal recognition remained scarce, as can be seen in successive four-year evaluation reports. The year before the researcher retired,

[5] https://sarra-h.teledetection.fr/?page_id=13

recognition was finally accorded with the hiring of a young researcher assigned to follow up the model's development.

Researchers can derive benefits from this design process that can, in turn, nourish their motivation. Developing software with a high TRL allows them to be identified as resource researchers by their colleagues, their institution, and external actors, especially donors, on a given topic. Embodying the concept of researcher-intrapreneur, some are almost identified with the software they have developed and keep developing. Having a usable tool and being easy to identify opens the prospect of future partnerships, an opportunity almost systematically cited as one of the keys motivating development beyond a simple prototype formalized by a scientific article. These partnerships may be in the scientific sphere, particularly in the setting up of new projects where the existence of a DSS with a sufficiently advanced TRL opens up possibilities in terms of methodology and involvement of non-researchers in the project. This was the case for Olympe, a tool designed to model farm management and strategies, co-developed by a CIRAD researcher and a team at INRA, the French National Institute for Agricultural Research, from 1999 onwards. The CIRAD researcher asserts that its existence was a strong justification of project proposals. Partnership opportunities also may exist in the non-scientific sphere, with the emergence of new questions and new contexts, which may contribute to pushing forward an existing DSS or starting a process of design and development on innovative topics. For example, a web application for mapping the progress of the sugarcane harvest developed on La Réunion island and little used on-site was spotted by a sugar agro-industrial company in Thailand. This led to the signing of several partnership agreements involving projects for the researchers and valuable financial returns for CIRAD.

Most of the researchers interviewed adhere to the conventional role of advancing knowledge, with some adding advising on public policies, looking for funding, and training younger researchers and students. However, some researchers expressed frustration regarding the limited impact associated with this traditional role. These individuals were motivated by and placed greater value on achieving direct societal impact. Interestingly, although half of the researchers interviewed had undergone training specifically focused on impact as part of CIRAD's institutional strategy, none of them perceived it as useful in driving the development of the TRL of their DSS. It is important to note that the training provided started in 2011, which was relatively recent compared to the ongoing developments of DSS

5.1.2. Perception of the institutional context

Despite this institutional strategy for impact, CIRAD historically did not encourage researchers to increase the TRL of a DSS by not including this as a factor for consideration in their career advancement. This context was experienced differently by the researchers interviewed and seems independent of the level of TRL achieved. Senior researchers who previously had been involved in the development of a DSS judge the institution's position in terms of internal recognition to be neutral at best, and unfavorable at worst. For some, the rise in TRL beyond the publication of the prototype "*is at best neutral in terms of career, and even unfavorable if one takes into account the time spent developing the tool, writing the manual, advertising it, etc. unless you hit the jackpot in financial terms*". Others consider that the most significant recognition comes not from the institution but rather from partners or certain colleagues interested in the product. Finally, one researcher declared that his project is perceived as not sufficiently in line with CIRAD's strategy, which has led to a lack of recognition, or even a negative appreciation, although the product is based on scientific results obtained within the institution.

These considerations often lead researchers wishing to increase the TRL of their prototypes to assume the responsibility of addressing legal aspects (intellectual protection), making their products accessible (e.g., putting them online), maintenance, and marketing. As a member of the senior management recognizes: "*when there is a tool, the researcher is in charge of everything, whereas in a company, there is a salesperson behind it*".

An example of a DSS currently under development may reflect a recent shift in the way the institution approaches this type of activity. SoYield, which supports the mango value chain by estimating localized production levels, sprang from a recent Ph.D. dissertation and promising research. It was located at TRL3 when we started our survey in 2020 and is considered by the researcher to be at level 7-8 in 2023. Co-design methods were used extensively throughout its development. The researcher has convinced his hierarchy to shift his main work from standard research to project management for 10 years. He asserts that engaging in *"DSS development is a voluntary and career choice"*. He sought for and has received strong support from CIRAD. This is due to the rise of the "research valorization" function within CIRAD and to a socio-economic context that is considered favorable due to the enthusiasm among value chain actors. The project leader, a 35-year-old agronomist and modeler, feels confident about acting as an intrapreneur. He considers that he has embarked on its development thanks to promising internal recognition and the support of several internal services: "*The valorization, transfer, legal and computing services support us in the implementation of this project [...] and support is underway for contracting and developing an economic model*".

5.2. Managers' and support services' perceptions of intrapreneurs and TRL increase activity

5.2.1. Managers

Seven of the eight interviews conducted with CIRAD's senior management indicated that, overall, the institution does not prioritize DSS design, development, and dissemination activities despite CIRAD's clear and recent commitment to the "digital revolution" and impact. Due to his interest in digital issues and his involvement in an institute focusing on digital agriculture, only one manager had a clear vision of the strategy, resources, and issues related to DSS. Although DSS are listed by each relevant research unit in their five-year evaluation reports, the managers did not appear to have clear or comprehensive knowledge of the products in existence. DSS were not well defined in the minds of our interviewees. They linked them more broadly to digital tools, which are very diverse within the institution, and include modeling tools that do not aim to support the decision-making of actors without research support, such as serious games (agent-based models for natural resource management), information support tools such as botanical identification, and even internal information management. Some of our interviewees expressed an interest in the inventory of these tools and raised questions about their visibility.

When known to managers, DSS were perceived as being one class of products among others, such as seeds, vitro plantlets, genetic sequences, and policy briefs. The institution's explicit strategy concerning the steps to be taken to promote finalized research products, notably via the setting up of a technology transfer office and incubation systems, was not well known to the management team. As a top manager warns, "*design and co-design may involve CIRAD researchers, but the final development must be carried out with private development specialists (while taking care to retain rights)*", all the more so since "*the programming time spent to make DSS accessible to end users is generally grossly underestimated by researchers*".

Moreover, there was a general agreement among the managers that this type of activity should "*be set up like any other project*", i.e., organized in an ad hoc and adaptive way. One interviewee added: "*Who can better 'sell' the technology than the one who created it?*" This organization can take the form of a small team, for example, and be based on internal project support programs, not specific to a DSS or digital tools in general, as is the case within CIRAD. The activity of finalizing decision support tools was linked to the issue of knowledge transfer, which requires "*creating subsidiaries or going through SATTs (technology transfer acceleration companies)*". However, the finalized and visible achievements were proudly cited, such as Smart'IS[6], which is part of this study, or Pl@ntNet[7], which is not a DSS stricto sensu but a botanical determination tool now widely used by a large range of actors.

Apart from one previously mentioned manager, the managers interviewed recognized a lack of knowledge about the institutional organization on the subject, as one of them said: "*There is no institutional strategy, it is up to the researchers' willingness*". In contrast with DSS, seeds, plantlets and genetic material benefit from a long tradition of finalized development. There is a well-mastered pipeline, including a person specifically appointed to valorize these resources, and several spin-off companies dedicated to producing, conserving, and selling them. While the pipeline is well-mastered and the problems known, many questions remain and are solved case by case, such as intellectual property on how to manage such products for the benefit of the public, especially in countries with a weak public sector. For management, the situation is even more complicated for DSS which are not conventional scientific outputs.

5.2.2. Transfer and valorization

The transfer and valorization team's primary objective is to contribute to creating an impact. They emphasize that traditional product pipelines, which involve patents and contracts with royalties, are well-established and understood. However, when it comes to algorithms or applications, the team finds that the internal policy regarding copyright and licensing to be unclear at present. This situation requires a creative approach to promote the external use of such tools while considering their positive societal impact, the business requirements of private companies, and the collection of royalties. CIRAD is hesitating to encourage in-house development because it lacks the necessary resources for maintenance, servers, and human capital. Additionally, discomfort remains in engaging with AgTech as a business. An example of this is the reluctance to invest in the capital of a start-up dedicated to commercializing SoYield, despite the tool having been developed within CIRAD and having received significant institutional support. The teams also highlighted the ethical considerations surrounding the use of these tools, particularly those that involve data collection. It is a complex subject with no absolute answers, especially when considering the public service aspect.

An effort to organize digital production is emerging through the appointment of a "task officer for open science and research data". Research institutes have a clear mandate of data production and provisioning of open data. This mandate is driven by European regulations. The dynamics of digital outputs thus created, notably with the implementation of a dataverse where software can be deposited, as well as the publication of software papers facilitating the transfer of source codes (e.g. Coste et al., 2021), could enhance the visibility of DSS within the institution. DSS

[6] https://smartis.re/HOME

[7] https://plantnet.org/

researcher-intrapreneurs therefore remain almost invisible to upper management, just as the technologies they develop remain off the radar of institutional strategies.

Beyond motivations and internal strategies, researcher-intrapreneurs need to invest resources to climb the TRL ladder. We investigate the way researchers manage to bring their DSS to higher TRLs in the following section.

5.2.3. IT component

The management of the computing component of a DSS project is crucial for its success, which generally cannot rely solely on thematic researchers and requires specific and evolving skills. At CIRAD, the Information Systems Department brings together a large proportion of the computer engineers employed by the institution. However, their activity focuses more on the design, development, and monitoring of internal management tools than on the development of digital tools resulting from scientific research for external use. On request, CIRAD provides servers and hosts web pages[8]. However, creating and maintaining these sites again requires dedicated computing skills.

Computer engineers working in research teams are a scarce resource. They work on projects that are *"mainly non-innovative"*, or even *"rather repetitive"*, mostly at low TRL levels. They emphasized teamwork, which can take precedence over the innovative nature of the project. Knowledge and recognition of their skills seem to be little shared. One computer engineer stated that *"our skills are not well known by researchers who think they can do everything on their own"*, or *"they are often devalued or overvalued"*. Many misunderstandings are felt and evoked by another computer engineer: *"The assumptions about computing on the part of people from various backgrounds are often a bottleneck in communication and sharing"*, except in the case of insertion in a team dealing explicitly with these DSS issues where *"the needs in computer development are shared and expressed"*. These misunderstandings weigh on the individual motivations of computer engineers. Their limited availability coupled with insufficient funding do not encourage them to spend too much time developing finalized tools.

5.3. Researcher-intrapreneurs climbing the TRL ladder

Developing a DSS necessitates personal capabilities, human resources, and internal or external funding and support.

5.3.1. Personal capabilities

A digital tool requires computing. Although a positive correlation appears between the computing skills that researchers attribute to themselves and a rise in TRL, this skill does not seem indispensable (Table 1). Out of the six cases which had reached a TRL7 or higher, three are led by researchers who consider themselves to be very little (1) or moderately (2) literate in computing. Incapable of climbing the TRL ladder alone, these researchers acted as intrapreneurs by searching for and mobilizing resources available in their immediate environment (geographical location, research team), like fellow researchers competent in computing and professional computer engineers, or by setting out on a quest for additional external resources such as project funding or partnerships with an external institution or industry.

In the other cases, computing tools were developed by the researchers themselves. Of these, two cases were cited as the work of single individuals. In some cases, the researchers are the sole

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[8] For instance, http://capsis.cirad.fr/.

developers on their research team. Once again, although the researchers are skilled in computing, they needed to call on other people and resources since the skills required were too diverse, and the development time too long, to be carried out by a single researcher. As described by a computer-savvy researcher: "*I developed the data processing algorithms, but I could not have administered the server on which the DSS runs, developed the information system, the user interfaces, translated the algorithms into web language (PHP) or low-level language (shell scripts under Linux). This was possible thanks to the presence of a computer engineer on my team and subcontracting with a software firm.*" Individual intrapreneurs' computing skills are therefore seen as helpful in reaching a higher TRL, without being either necessary or sufficient.

5.3.2. Resources mobilized to develop a DSS

Beyond personal abilities, several resources may be mobilized to develop DSS. Researchers need to apply for, and compete with others over access to, these support services. These resources may be human, such as team colleagues or surrounding researchers. The institution provides internal support services that may be called upon for specific topics. Researchers may ask for external support through collaborations with industry or funding of research projects.

In the vast majority of examples, researchers mentioned little to no use of internal support services. A notable exception concerns the legal aspects of intellectual property, for which they are often mobilized. The internal information systems division is mostly devoted to proposing and maintaining services for CIRAD internal activity rather than to providing support in application development, and researchers most likely used the support of external developers hired specifically for this task.

With one exception, all of the researchers used external funding obtained through research or industry projects and paid time devoted specifically to increase the TRL. These projects included funds to pay developers. The exception is Smart'IS, a project that aimed to gather all of the DSS developed on La Réunion, a French island located in the Indian Ocean. CIRAD is heavily dependent on public funding for its activities in La Réunion. The funding agencies suspected CIRAD of *"keeping everything gathering dust in a drawer",* as expressed by a computer scientist, and threatened to cut some of their funding. CIRAD decided to use internal funds to support the Smart'IS project for the strategic purpose of making research visible. Technically, the project was easier than others due to the small size and geographic coherence of the island. It also served as a *"showcase"* of CIRAD capabilities outside La Réunion. In contrast, there was no mention of working with technology transfer acceleration companies, and only two projects were managed in direct collaboration with start-ups.

5.3.3. Specific IT challenges

The interviewees mentioned challenges which are specific to creating finalized and useful DSS directly from research. First, some research topics result in models that are too narrowly focused and cannot easily be translated into a DSS that actors could use directly for their decision-making process. Such models are bricks of bigger systems that can be tailored later for external use. Second, maintaining and keeping the tool up to date with more advanced or modern programming languages is a challenge. The researcher responsible for Cohort, a support tool for designing mixed crop-livestock production systems at the farm level, struggled to migrate from an Excel spreadsheet to a dedicated app. Olympe experienced the same difficulty due to initial developments in C++, while the researchers wished to migrate to a modern and open-source language. The migration was initiated thanks to project funds but were stopped due to a subsequent lack of funding. Finally, researchers that are not developers themselves mentioned the difficulty of employing qualified developers over the long term since salaries are much lower in research compared to the private sector. Only a few developers, motivated mostly by public interest, remain for a long period in the institution. Many mentioned that they had to make do with interns or short collaborations with developers when funds were available.

6. Discussion

In this article, we sought to characterize the intrapreneurial processes associated with the development of DSS. We aimed to test the hypothesis that researcher-intrapreneurs and their institutional environment were aligned to bring science and society together through the finalization of DSS in a digital and impact-oriented research era. To do so, we investigated the motivations and contexts that led researchers to take an intrapreneurial path. We examined how and if these initiatives are received and supported by other actors in the applied agricultural research institution in which they collaborate: computer engineers, members of the technology transfer office team, and managers. To capture the interfaces that emerge - or struggle to emerge - between the motivations and actions of intrapreneurial researchers and the actors or institutional arrangements that surround them, we propose in this discussion to return in greater detail to the notion of alignment referred to in our introductory hypothesis. This notion, used in the field of organizational management, enables us to understand how strategies relating to certain sectors of an organization - communication, for example (Volk & Zerfass, 2018) - may or may not succeed depending on their level of alignment with the organization's general strategy. Applied to the field of sociotechnical transitions, it allows the identification of how alternative niches and technologies may or may not scale up depending on the potential alignment they have with the dominant sociotechnical regimes (Goulet, 2021). In the field of institutional change and entrepreneurship activities related to the academic sector, it embodies the widespread difficulty of creating synergies between organizational and individual levels (Eesley et al., 2016; Heinze and Weber, 2016). In the light of this notion, we propose here to explore the extent to which the actions of individual intrapreneurs are aligned or not with those of other players in the organization, and more broadly with the latter's major strategic orientations.

6.1. Individual motivations and the careful institution

At the individual level, our results are in line with Rigtering and Weitzel's (2013) findings, as intrapreneurship, *i.e.* getting out of the usual TRL1-3 loop, is primarily an individual decision, not necessarily aligned with institutional incentives or strategies. In our results, it is the most common situation, represented by trajectory T1 in Figure 1 (conceptual framework). In this regard, academic intrapreneurs resemble non-academic intrapreneurs. Although digital development processes are now better known than they were decades ago, researcher-intrapreneurs still often rely on their own resources outside the framework of their institution, and sometimes face skepticism from colleagues, which may be detrimental to the researcher's career advancement. Our results show that individual internal and external motivations are key, particularly the desire to have an impact beyond research, even if this desire does not stem directly from their institution's impact strategy. Interestingly, the individual possession of coding capacities is neither necessary nor sufficient. The motivation to communicate the existence of finalized tools to secure funding and expand networks also plays a role. In this way, such activities contribute to the traditional roles of research, as identified by Kyvik (2013).

Even though digital agriculture has become a main technological topic, the institution does not systematically provide support for extensive Technology Readiness Level (TRL) development, as it primarily focuses on more traditional and specific domains of agricultural institutions, such as vitroplants and genetic resources. As highlighted by Horner et al. (2019), it is prudent to act strategically by carefully selecting which digital tools to promote. While support services are available, a systematic strategic approach is applied to the development of "non-standard" research outputs, particularly since these outputs are uncertain in terms of direct financial returns. Yet promoting digital projects and allocating researchers' time to such projects may be strategic ways to acquire funding and establish the institution's reputation as a specialist in a particular field; these situations, which are in the minority in our results, are represented by trajectory T2 in Figure 1. While managers' views on developing digital tools to advanced stages seem to be changing, gaps in their understanding of such tools persist, indicating a misalignment between the words and deeds of institutional management (Simons, 2002). Thus, contrary to what our initial hypothesis suggested, the actions of the researcher-intrapreneurs are in most cases poorly aligned with those of the organization and the different categories of actors that make it up.

Both aligned and misaligned trajectories are represented in Figure 1. In the figure, we represented how motivation, new projects, career advancement, and institutional recognition were factors that could drive or impede progress along the path from proof of concept to usable DSS for trajectories 1 and 2. Researchers following trajectory 1 may see positive effects on the progress of their career, whereas trajectory 2 more often than not has negative effects.

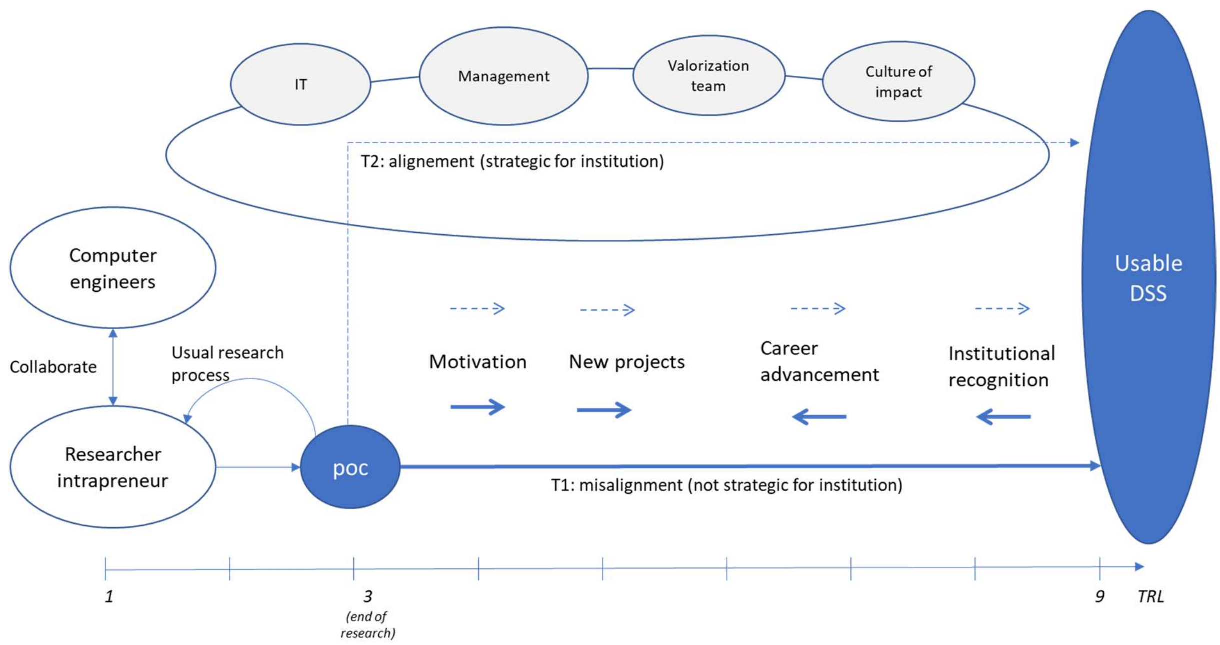

Figure 1: Conceptual framework of (mis)alignment of researcher-intrapreneurs and their institution taking the digital turn

Embarking on a digital transformation requires specific considerations, including mastering multiple languages, ensuring maintenance, managing data, and addressing ethical concerns. In addition, research does not necessarily revolve around topics directly linked to individual decision-making. Models often address specific and narrow situations and can hardly be of direct use for actors' decision-making. DSS are also developed in languages that may not be up to date in a rapidly evolving environment. Such tools may develop a legacy problem, such as the one experienced by banks with the COBOL language (Hajnal & Forgács, 2012). Finally, research institutes struggle to compete with private firms to attract senior or talented developers since salaries are much lower in the public sector and these skills are in high demand.

This leads us to consider which strategic choices agricultural research should focus on. The range of dimensions that must be addressed to increase TRLs, and the financial investment required, take researcher-intrapreneurs out of their usual realm of expertise and make them more project managers than research specialists. Research institutions may prefer that researchers devote themselves to what they are best at doing. Even if a product has economic potential, research institutions should weigh the relevance of pushing researchers to invest time in developing potentially profitable products and to compete with private firms that are better organized and equipped for such activities, as described by Birner et al. (2021). Nonetheless, to fulfill their mission of serving society, research institutes could focus on areas that serve the public interest and in which the private sector is uninterested due to limited financial returns or which could provide returns but with high ethical risks. Heimstadt (2023b) provides the case of an app initially designed to identify plant illnesses and provide agroecological solutions which ended up selling data to pesticide sellers. Ag4D institutions have goals such as participating in food security and diversity, preserving and selecting varieties, and advising the public sector with research-based policies. The same criteria applied to these outputs could be used to decide whether or not to devote researchers' time to DSS development projects. Intrapreneurship in such activities and ad hoc strategic approaches tailored to each tool seems inevitable for agricultural research institutions to fulfill their mission to bridge science and society most efficiently. Said differently, institutions could align with researcher-intrapreneurs' strategies on digital tools if the focus is on mission-oriented innovations compatible with values and major challenges they aim to tackle.

6.2. Limitations and future research

This study is limited in its generalizability due to its focus on a single institution and a small sample size. The examination also primarily revolves around researchers, upper-level management, and close collaborators, potentially overlooking perspectives from other organizational levels or partners outside of the boundaries of the research organization. Future studies could mitigate these limitations by expanding the research to encompass multiple AR4D institutions or applied research organizations in diverse fields since strategies, internal organizations, and researchers' mindsets may differ from those found in this case study. Furthermore, the study's strictly internal focus does not consider the point of view of external demand or the interactions with industry. Considering such actors may allow for a more varied view of the blurred frontier between research and the outside world. Including participants from different organizational levels, such as middle and local management, and colleagues from other institutions, also could provide a more comprehensive understanding of intrapreneurial dynamics and the variety of internal support, exploring other level of alignments within and outside of research organizations.

7. Conclusion

In this article, we aimed to understand why and how individual researcher-intrapreneurs pursue the mission of an agricultural research institute of bridging science and society through the development of DSS, and whether that commitment aligns with their institutional environment. In interviewing various actors within an AR4D institution, including researchers, managers, computer scientists, and support services, we had two aims: investigating the motivations of and means deployed by individual researchers in their organizational context, and identifying strategic elements that need to be considered by the institution when approaching a DSS as an outcome of research.

The results of our study confirm that researcher-intrapreneurs' motivations, especially the will to have an impact, are essential if they are to move beyond their traditional roles and behave intrapreneurially. Although the output is a digital tool, coding capacities are not essential for the lead researcher. We also show that institutions should think critically and strategically about investing in a precious resource, namely the time spent by researchers in finalizing specific tools directly usable by actors. Whilst research organizations are trying to develop a culture of impact within their staff and procedures, they are struggling to manage and benefit from the experience of intrapreneurs. In turn, intrapreneurs have difficulty finding support within their environment, despite its a priori favorable nature. We are therefore in a position to refute the hypothesis put forward in the introduction: instead of alignment between the practices of the researcher-intrapreneurs and the actors or institutional mechanisms that surround them, we are mostly in the presence of misalignment. Lastly, research institutions may have difficulties in competing with the private sector due to unequal means and objectives, and should consider investing in subjects that would serve the public interest without being profitable per se. They should therefore endeavor to develop targeted alignments that are faithful to the missions and values they have set themselves, and to which they want their researchers to adhere.

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Appendix A

Characteristics of the 16 DSS surveyed

DSS name	Objective	TRL	Year of initial design	Year of last developments	Expected TRL increase	Target supported audience[1]	Target user audience[1]	Access
ACV Cirad	Life Cycle Assessment (LCA) applied to agriculture and other tropical areas, products and value chains	6	2012	2020	No	C, F, H	D, F, I,	On demand
AFA	Analysis of the agri-food chains	3	2005	2020	In progress	C, F, I,	C	Webpage in progress
ALBORUN / ARBOCARTO	Spatial modeling of the population dynamics of *Aedes albopictus* ('tiger mosquitoes')	7	2016	2020	Yes	D	D	Transferred to the client
Biotex	Extraction of terms from text data in English, French and Spanish	5	2012	2015	No	H	C, I	http://tubo.lirmm.fr/biotex/index.jsp
CAPSIS	Forest growth simulation platform	4	1994	2020	No	F, H	D, F	http://capsis.cirad.fr/capsis/transfer
CLIFS	Support tool for designing mixed crop-livestock production systems at the	5	2005	2020	No	A	B, C, E, I, J	https://doi.org/10.18167/DVN1/NZHWQQ

	farm level							
Cohort	Support tool for designing horticultural production systems at the farm level	6	2016	2020	No	A	B, C, E, I, J	https://www6.paca.inrae.fr/psh/Modeles-et-logiciels/Cohort
DairyPlant	Support tool dedicated to dairies for designing payment systems according to their portfolio of processed products	4	2013	2015	No	E, F	B, C, E, F, I, J	On demand
Epidvis	Automated monitoring in the field of animal epidemiology. Tool dedicated to the construction of queries to collect relevant documents via the internet	3	2015	2018	No	H	C, I	http://advanse.lirmm.fr/Vis/index.html
MASH	Web application for mapping the progress of sugarcane harvest	9	2016	2020	No	F	D, E, F, H	https://smartis.re/p/MASH
Olympe	Tool for detailed technico-economic analysis of farms	9	2000	2003	Yes	A, B, E	I, J	http://www.olympe-project.net/
PADI-Web	Automated monitoring in the field of animal	6	2015	2021	Yes	H	C, I	https://padi-web.cirad.fr/fr/

(RS4)	epidemiology							
Pistes (RS9)	Creation of a network of skid trails	7	2010	2014	No	D	D	On demand
PixFruit (RS10)	Acquisition, management and sharing of production data for the structuring of tropical fruit chains	6-7	2019	2023	Yes	A, B, E, F, H	A, D, E, F	Free smartphone application
SARRA (RS11)	Crop model adapted to the analysis of climate impact on crop growth and yield potential in tropical environments	8	2002	2021	Yes	H	I	https://sarra-h.teledetection.fr/SARRAH_Home_En.html
Victoria (RS12)	Assistance in planning and monitoring pineapple harvests	5	2015	2019	No	A, E	A, B, E	https://smartis.re/VICTORIA

[1] A: Farmers / B: Advisers / C: Consultants and experts / D: Technical staff / E: Cooperatives / F: Private firms / G: Consumers / H: Public decision-makers / I: Researchers / J: Students