

How different agricultural research models contribute to impacts: Evidence from 13 case studies in developing countries



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ABSTRACT

In a context of a severe funding crisis, donors and policymakers expect increased accountability from research organizations and convincing proof that public investments in research have significant and positive societal impacts. This article takes stock of the lessons learned from the use of a method (ImpresS) designed by CIRAD to analyze the impact of research undertaken in partnership with a range of different actors in a developing-country context. The method uses a case study approach, and relies on the evaluation of the impact pathway and on contribution analysis. Thirteen case studies were selected to represent the diversity of partnerships, research activities and types of innovation. The results confirm the diversity and complexity of the innovation processes encompassing the non-linearity of changes over extended periods, the diversity of impacts, the shifting roles of actors engaged in the innovation process, and the diversity of activities carried out by the research community to contribute to outcome and impact generation. Interactions between researchers and other actors throughout the innovation process appeared to play key roles along the impact pathway. Based on the 13 case studies, we identified four generic models through which research contributes to impact: participatory transfer of knowledge and technologies, co-design of innovation, support for the innovation process, and promotion of open innovation. Our results underline the need for research institutions to recognize and accept the diversity of functions fulfilled by researchers if they want to contribute in an effective manner to the generation of impacts. Another challenge is to learn how to take advantage of clusters of projects embedded in innovation pathways in order to sustain research activities over a long timeframe.

Significance statement: Impact evaluation is increasingly being requested from the research community as a measure of accountability by both donors and civil society. Conducting it properly is challenging, especially in the context of developing countries. Quantitative studies are often biased toward expected and tangible impacts. Complementary qualitative approaches are focused on understanding causality and are more in line with the actors' participation in impact evaluation. CIRAD has developed a method and used it to assess 13 case studies involving research conducted in partnership in widely differing environments. Some main lessons learned include the long timeframe needed for impacts to be achieved, the diversity of impacts the research community needs to consider, and the multiple roles played by the research community in co-developing outcomes with

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diverse stakeholders. Results show that the research community can contribute to impacts by using several models of intervention.

1. Introduction: what type of models should the research community use to achieve impacts?

Understanding and improving the contribution of agricultural research for development (AR4D) to global food security and poverty alleviation through sustainable agricultural is becoming increasingly important. In a context of a funding crisis, donors and policymakers expect increased accountability by researchers and their institutions and concrete evidence that public investments in research have significant and positive societal impacts (Foray et al., 2012, Morgan et al., 2017). However, impact evaluation is difficult because AR4D cannot solve societal challenges on its own.

Diverse organizational models of innovation detailing the interactions between the research community and other actors can be found in the literature. One such model is the “transfer of knowledge and technologies” in which the research produces outputs that are directly used by other actors (Röling, 2009). This model was the basis of the Green Revolution in which new technologies (e.g. improved seeds, chemical inputs) were developed by the research community, disseminated by extension mechanisms, and adopted by farmers. But such a prescriptive model, while still being used, is subject to criticism for its inability to solve the complex problems inherent to agricultural development, such as environmental and social issues, and for its simplistic assumption of passive adoption of technologies by farmers (Ekboir, 2003). Another innovation model, based on a systemic perspective, stresses the fact that innovation is produced by interactions between a variety of public and private stakeholders within the framework of an agricultural innovation system (AIS) (Hall et al., 2003; Touzard et al., 2015). In this situation, agricultural research may contribute to innovation processes by operating through different types of partnerships and the use of participatory research methods (Röling, 2009; Douthwaite and Hoffecker, 2017). However, this systemic innovation model is sometimes criticized for its inability to easily produce generic solutions with the potential to be adopted on a large scale (De Janvry et al., 2011). More detailed innovation models are described in the literature and analyze the role of research when research does contribute to innovation. They combine various elements of the “transfer of knowledge and technologies” model and the “systemic innovation model”. However, these models usually pertain more to the industrial and business domain than to the agricultural domain (Matt et al., 2016). Tidd (2006) in his literature review identified five generations of innovations models in the industrial and business domain depending on variables such as the types and roles of stakeholders involved (including the research community), the types and intensity of interaction between stakeholders, and the level of control over the innovation process by the non-research stakeholders. The author compared the push-pull technology model with other models developed for intervening in complex systems and working with networks of actors. Amongst alternative models, the popular chain-linked model proposed by Kline and Rosenberg (1986) focuses on the intensity of interactions between the researchers and other actors during different phases of the innovation process (from market identification to final product development and distribution). Another example is the open innovation model which describes the flexible collaborations between stakeholders (including researchers) who agree to freely share the knowledge and the risks (Chesbrough, 2003).

Despite a long-standing interest in the subject (Horton and Mackay, 2003), few studies have assessed how AR4D contributes to impacts or explored its link to the application of the different innovation models (Donovan, 2011; Colinet et al., 2013). These considerations led the French Agricultural Research Centre for International Development (French acronym: CIRAD) to invest collectively in an effort to document

if and how the research it conducts in developing countries in partnerships with national research organizations fosters innovation and produces impacts. To this end, CIRAD developed a specific evaluation methodology called ImpresS (Impact of Research in Southern countries). On the basis of a cross-analysis of 13 case studies evaluated by the ImpresS method, this article has the goal of analyzing how research contributes to impacts in order to identify the different models of AR4D that contribute to impacts. Our results should provide generic insights on how agricultural research organizations can enhance their contribution to impacts.

2. Method

2.1. The participatory impact evaluation method used in the case studies

The ImpresS methodology does not focus on the attribution of impacts to research, which is often based on economic and statistical approaches (Joly and Matt, 2017). It draws instead on a set of key concepts: case study research (Yin, 2009), impact pathway evaluation (Douthwaite et al., 2003), and contribution analysis (Mayne, 2001). These choices originated from the scientific interest in understanding the processes and mechanisms that enable agricultural research to contribute to impacts. The evaluation followed participatory principles (Baron and Monnier, 2003) to arrive at a shared perception among actors of the specific process being evaluated and its effects (Habermas, 1984) and to improve the quality and relevance of the evaluation by mobilizing different kinds of knowledge and perceptions (Ridde, 2006). To this end, a range of different actors took part in workshops, focus groups and surveys to characterize the innovation process and the consequent impacts. They also took part in a final workshop to discuss, refine, and validate results.

For each case study, the evaluation using the ImpresS methodology started by reconstructing, in collaboration with the actors, the narrative of the innovation process, including the roles played and strategies adopted by every stakeholder in the innovation process. We focused in particular on the activities of researchers, which included capacity building activities, and we analyzed the types and intensity of interactions between researchers and other actors, including public ones. To do so, we analyzed three to eight specific and concrete situations of interactions involving research for each case study by using approaches based on learning theories (Toillier et al., 2018). In a second step, the impact pathway approach was mobilized to map the causal chain linking the inputs used by the research community, the research outputs, the outcomes, which are generated when actors use and transform the outputs, and, finally, the impacts, which are the long-term changes arising from the outcomes. Impacts were identified by collecting “descriptors of change” from the actors involved in the innovation process which express their perception expressed, by using their own words, of what has actually changed as a result of the intervention. Each impact was characterized by a set of quantitative and qualitative indicators that accounted for the changes that took place between the start of the innovation process and the evaluation. Values for these indicators were collected through *ad hoc* surveys, interviews, focus groups and secondary data.

To implement the ImpresS methodology, 13 case studies were selected by the authors from a pool of 54 candidate case studies drawn from CIRAD's research interventions to illustrate the diversity of partnerships, research activities and types of innovations to which CIRAD's research has contributed in the past 40 years (Table 1). In this selection, we observed 9 case studies with research activities stretching back several years into the past and with observable and stabilized impacts.

Table 1
Description of the case studies.

Domain	Description of the case studies	Name of the case study	Research focus	Start of the research intervention	Geographic area
Plant identification	PI@nNet (ongoing)		Development of a software application for plant identification and of a collaborative platform for data and knowledge sharing	2009	Global
Genetic improvement	Groundnut breeding (ex post)		Breeding groundnuts for drought resistance and seed production	1999	Senegal
	Participatory breeding of sorghum (ex post)		Breeding sorghum with participatory research and seed production	1995	Burkina Faso
	Breeding of rainfed upland rice (ex post)		Breeding rainfed rice for upland areas and seed production	1984	Madagascar
	Tseise fly eradication (ongoing)		Improving animal health by eradicating the tseise fly which transmits animal diseases	2005	Senegal
Plant and animal health	Control of white grubs (ex post)		Development of integrated pest management (IPM) to reduce infestations by a key insect pest of sugarcane	1981	France/Reunion Island
	Traps for coffee berry borers (ex post)		Experiments with and marketing of traps for coffee berry borers	1997	Dominican Republic
	Animal health surveillance (ongoing)		Design of control systems (institutional arrangements and methods) for surveillance of animal diseases	2003	Vietnam
Post-harvest processing	Fonio huller (ex post)		Innovation in post-harvest technology for fonio	1994	Mali/Burkina-Faso
Integrated resource management	Recycling of organic residues (ongoing)		Support for new organizational arrangements to manage green residues at the territorial level	2008	Reunion Island, France
	Manure management at the farm level (ex post)		Design of innovations pertaining to manure management in mixed farming systems	2005	Burkina Faso
Market	Integrated water management (ex post)		New arrangement and co-design of innovations for water resources management	2005	Indonesia
	Wine geographical indications (ex post)		Support for institutional and market innovation to promote local wine	2004	Brazil

We labelled these case studies “*ex post* assessments”. The remaining 4 case studies were those in which research activities were still underway (between 8 and 14 years) and the impacts are not fully stabilized or not still clearly observable. We labelled these case studies “ongoing assessments”. For each case study, a local evaluation team led jointly by a CIRAD researcher and a local research partner carried out the assessment during 2015 with the support of the ImpresS methodological team. A database was built to homogenize the narrative of actors, impact pathways, and impacts by using a set of common variables across all case studies.

We need to highlight two points to help the reader assess the relevance of our method and our results. First, the internal process of the selection of case studies tended to identify “success stories” and thus we cannot draw lessons regarding the impact at the level of the research organization as a whole. Second, the evaluations were not external evaluations providing what we could call “neutral evaluations” but were internal in nature and aimed at supporting learning processes for the stakeholders, including researchers, and at drawing useful lessons.

2.2. Cross-analysis of results and identification of generic lessons

All through 2016, the results of the case studies were cross-analyzed and the lessons learned identified. Use of the database allowed us to make the case studies more robust and more comparable. The cross-analysis led to the definition of 11 impact domains. For each case study, an expert panel (Joly et al., 2015) assessed the change based on two criteria per impact domain: the intensity of change to characterize the degree of variation of an impact, and the magnitude of the change to characterize the number of people or the geographic area concerned by the innovation. Reliable quantification of these impacts was challenging given the diversity of innovations and impacts.

Both the analysis of the researchers' activities and the analysis of the impact pathway, which characterizes the interactions between the researchers and other actors to produce outputs and outcomes, were used to identify different research models of intervention and design a typology of these research models. A three-day workshop attended by representatives of all the case study teams and all the authors of this article allowed us collectively to analyze and discuss the results and to draw generic lessons. More details regarding the methodology (Barret et al., 2017) can be found at <https://doi.org/10.19182/agritrop/00005>.

3. Results

3.1. Agricultural Research for Development (AR4D) contributes to a wide range of impacts

The cross-case analysis confirmed the diversity and complexity of innovation processes in which AR4D is involved, including their non-linear evolution over periods that are usually long (spanning up to several decades), the diversity and shifting roles of actors engaged in the innovation over time, and the wide range of different activities carried out by each actor over time. A summary of the innovation processes including a timeline for the 13 cases can be found at <https://impress-impact-recherche.cirad.fr/ex-post/case-studies>. The diversity of situations analyzed in our 13 case studies naturally leads to a wide range of impacts, as summarized in Table 2.

However, and more surprisingly, for each case study this diversity was still significant, as illustrated by a radar diagram for one case study (Fig. 1, Ferré et al. (2018) for more details).

Impacts identified using participatory approaches such as ImpresS appear to be not only more varied than the impacts usually reported in the literature, which mainly focus on production and income, but also more varied than the impacts expected by the evaluation teams at the start of the evaluation. This was especially true for impacts pertaining to the “culture and living conditions” domain. Some of the impacts were negative, such as nuisance odors, increased use of insecticides for

Table 2
Impact domains.

Impact domain	Number of impacts reported by actors for each impact domain and across all cases	Number of case studies reporting this type of impact domain
Economic opportunities for firms and employment	19	6
Production and productivity for farmers and value chains	13	8
Household and farmer income	16	8
Food security and product quality	6	5
Environment, natural resources and biodiversity	14	8
Animal health	2	2
Quality of services for households and farmers	3	2
Culture and living conditions	9	7
Access to and use of information	8	5
Capacity to innovate	14	8
Institutions and public policy	8	4

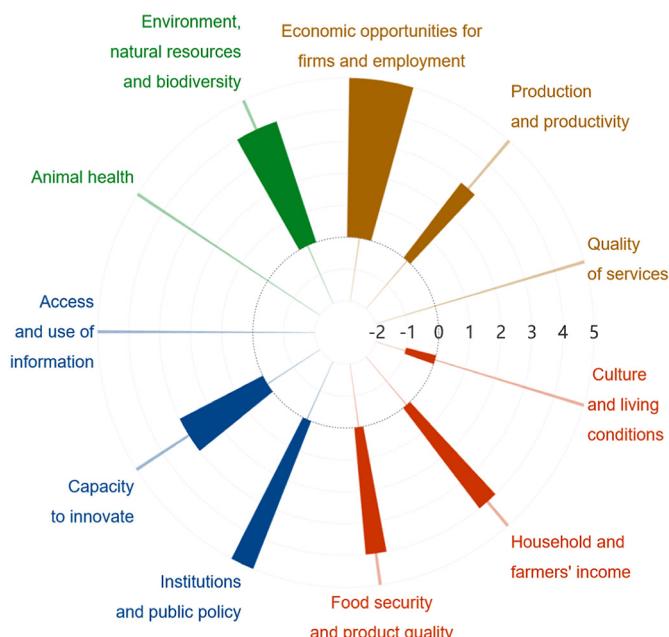


Fig. 1. Radar of the impacts of the participatory sorghum breeding case study. For each impact, intensity is ranked from -5 to $+5$ (weak, moderate, important, powerful, major) and the magnitude of the change is ranked from 1 to 3 (low, average, high) expressed by the thickness of the rays. (In this figure, the intensity is ranked from -2 to $+5$ due to the presence of only one negative impact.) The impact scores of 10 case studies can be found in supplementary information to this article (<https://impress-impact-recherche.cirad.fr/ex-post-case-studies>).

seed storage and threats to varietal diversity. However, other impacts were underestimated by the actors, often because they seemed to be of lesser interest to them, especially those pertaining to environmental issues. Significantly, it was observed that impacts build up over a long period of time, often 15 to 20 years or even more (Kristjanson et al., 2009). In the following sections, we analyze how research contributed to these impacts.

3.2. Co-producing outputs and outcomes with stakeholders is the key to generating impacts

Interactions between researchers and other actors throughout the innovation process emerged as key causal mechanisms that may help generate impacts. At the level of outputs, and especially in a context of participatory research, these interactions led to a diversity of products including new knowledge, methods, technologies, training modules, and experimental networks. At the outcome level, interactions between

different sets of actors (such as farmers, farmers' organizations, private firms, NGOs, public organizations) led to a wide range of outcomes: new agricultural or management practices for individuals or organizations, new organizational arrangements such as coordination mechanisms, innovation platforms, or networks for sharing experiences, as also the implementation of new norms or policies. Fig. 2 illustrates how research outputs led to several outcomes in the breeding of rainfed upland rice case (for more details, see Breumier et al. (2018)). The impact pathways of all 13 case studies showing the complete range of outputs and outcomes, and the relationships between outputs, outcomes and impacts can be found at <https://impress-impact-recherche.cirad.fr/ex-post/case-studies>.

In a “transfer of knowledge” model, researchers are usually not expected to participate in production of outcomes but instead are supposed to focus on producing scientific knowledge and proposing new technologies. In the systemic innovation model, vibrant interactions between researchers and other actors are needed to solve complex problems and address sustainability issues (Clark and Dickson, 2003). Our results show a more complex picture. In every one of our case studies, such interactions represented a major contribution to generating outputs and outcomes. Three inter-related factors concerning these interactions played key roles in strengthening innovation processes.

First, the existence of a core team of researchers and experts willing to take risks and to act as innovating agents played a key role in the eventual success of the innovation. For instance, in the participatory sorghum breeding case study in Burkina Faso, the CIRAD researcher decided to break away from conventional breeding methods used until then in the region by involving farmers actively in the breeding scheme.

Second, the quality and intensity of interactions between researchers and other actors shape the innovation process to a great extent (Kristjanson et al., 2009). Our results showed that in the early stages of the innovation, the interactions tend to be based on informal exchanges aimed at building trust and identifying options for action. In the final stages, the interactions are usually based on more formalized mechanisms within the framework of multi-stakeholders committees or innovation platforms and aimed at planning and monitoring activities.

Third, the quality and intensity of interactions that may take place with policymakers or public actors at all stages of the innovation process are especially important in creating a more enabling environment and in ensuring the effective scaling of the innovation (Cash et al., 2003). In the case studies, researchers interacted with policymakers in several ways and in pursuit of a variety of objectives: co-producing knowledge, aligning research activities with existing political agendas, facilitating access to funding, and designing new public policies. However, in the 13 case studies, policymakers approached research institutions to solve a problem in only three cases and public actors participated in the entire innovation process in only four. These contrasted results demonstrate that it is not easy for researchers to interact

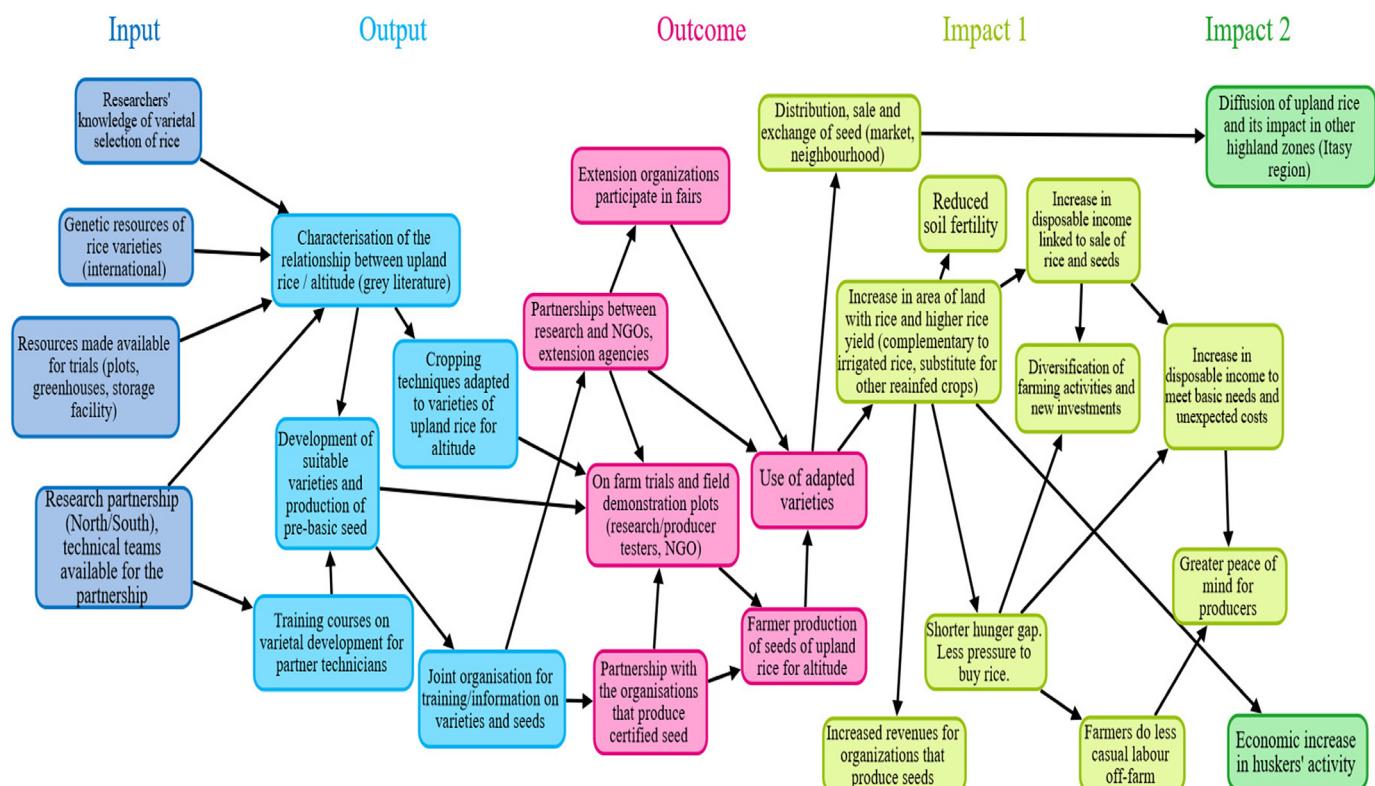


Fig. 2. Impact pathway in breeding of rainfed upland rice case study.

with policymakers in this manner and that perhaps the lack of interactions in some cases limited the process of scaling of the innovations concerned.

3.3. Researchers perform a variety of functions along the impact pathway

It was observed that due to the complexity and duration of the innovation process, researchers performed a variety of functions at different stages of the impact pathway. The cross-case analysis revealed five key generic functions: (i) knowledge production and dissemination, (ii) co-design of innovations, (iii) resource management, (iv) support and promotion of innovation, and (v) capacity strengthening (both in formal and informal settings). Capacity strengthening of all actors, including the researchers themselves, appeared to be especially important for the production of outcomes and the generation of impacts (Toillier et al., 2018) and is often overlooked or even disregarded in impact assessment. Diverse capacities were strengthened: technical – to implement new practices; managerial – to access and use resources; the capacity to experiment and learn; and the capacity to interact with others and, in particular, to participate in policy dialogues. Together, they enabled actors to improve their capacity to innovate (Leeuwis et al., 2014). Researchers were not always involved in capacity strengthening activities. However, we analyzed 60 learning situations in which researchers intervened in different roles as experts, trainers, coordinators, facilitators, and also as observers or learners themselves. This shows that there was a considerable diversity at the level of planning and control that researchers were able or willing to exert over the learning process.

On the whole, the functions researchers performed in a given innovation process depended on several factors: the importance of scientific knowledge in the innovation process, the researchers' willingness and capacity to interact with other actors, the capacity of other actors to participate or lead the innovation process, and, finally, the socio-technical context in which the innovation was developed. The cross-case analysis suggests that in the context of a developing country,

often because of weak institutional arrangements and a paucity of available specialized human resources, AR4D can and perhaps must fulfill functions that, in other contexts, are usually fulfilled by other actors.

3.4. The research intervention models are more diverse than expected

The impact pathways observed across the 13 case studies were extremely diverse, varying in complexity, and with many causal links that led to the impact. The way interactions between researchers and the other actors of the innovation were structured was a decisive factor in shaping the impact pathways (Joly et al., 2015). Building on the work of Tidd (2006) and based on our results, we identified three key variables that explain the types of interactions between researchers and other actors (Table 3): (i) the importance of scientific knowledge in the innovation process and the level of control the researchers had over the new technologies being proposed, (ii) the research approach adopted, based on the researchers' perception of the objectives to be achieved and the strategic partnerships they established with non-research organizations, and (iii) the role of the other actors in contributing to or leading the innovation process based on their capacities and resources.

Based on this analysis, we found four "archetypal" models of research interventions. A "model of research intervention" is a representation of the interactions between researchers and other actors. Each model serves different purposes and different levels of influence by the researchers are exerted over the impact pathway followed in each innovation.

3.4.1. First model: Participatory transfer of knowledge and technologies

The rainfed upland rice breeding program in Madagascar and the tsetse fly eradication program in Senegal are both good illustrations of the "participatory transfer of knowledge and technologies" model (Table 3). In this model, the researchers had a clear initial perception with defined objectives and a relatively straightforward strategy to achieve impacts. They could exercise quite a tight control over the

Table 3
Analysis of the research models.

Research model	Name of the case study	Level of importance of scientific knowledge and control over technologies	Research approach	Role of other actors on the innovation
Participatory transfer of knowledge and technologies	Groundnut breeding	High: control of genetic resources and breeding techniques	Clear perception of objectives to be achieved; Regular cooperation with the seed producers and the extension system to promote the seed and the extension	Limited influence on innovation: Farmers adopt or reject the variety, seed production supervised by researchers
	Breeding of rainfed upland rice	High: control of genetic resources and breeding techniques	Clear perception of the objectives to be achieved; Regular formal and informal interactions with the extension system and seed producers	Limited influence on innovation: Farmers adopt or reject the variety, seed production supervised by researchers
	Tsetse fly eradication program	High: production of sterile flies and design of software to plan, implement and assess tsetse control	Clear perception of the objectives to be achieved; Strategic partnership only with public ministries to orient the actions	Limited influence of farmers on innovation: Farmers do not contribute; Strong influence of public actors: they monitor the process
	Traps for coffee berry borers	High in the initial phase: the prototype to trap insects was designed in the CIRAD lab, tested in farmers' fields in Latin America	Clear perception of the objectives to be achieved; Regular interactions with public institutions and private sellers	Limited influence on innovation: Farmers and sellers can adapt the protocol to use the trap, farmers can adapt the trap, farmers can copy the trap, farmers can adapt the protocol to use the trap
Co-design of innovation	Participatory breeding of sorghum	High: control of genetic resources and breeding techniques	Clear perception of the objectives to be achieved; Strategic alliance with a group of farmers and a farmers' organization	Shared influence on innovation: definition of the characteristics of the varieties and evaluation of the experiments
	Control of white grubs	Medium: identification and formulation of biological agents, control over experiments	Clear perception of the objectives to be achieved; Strategic partnership with public and private organizations	Shared influence on innovation: private firm managed the production of the bio-agent, an association monitored the biological control process, public actors created an enabling environment
	Fonio huller	Medium: design of a hulling machine to sort fonio grains	Clear perception of the objectives to be achieved; Strategic partnership with a group of craftsmen, a few suppliers and public organizations	Shared influence on innovation: craftsmen adapted the prototype and defined their own marketing strategy, some suppliers developed the production of standardized equipment
	Manure management at the farm level	Medium: co-design of prototypes to make compost from manure, on-farm experimentation, follow up of soil fertility when using compost	Clear perception of the objectives to be achieved; Strategic partnership with farmers' organizations, many capacity-building activities by the researchers	Shared influence on innovation: Farmers adapted the prototypes and proposed improvements, farmers' organizations promoted the new practices
	Animal health surveillance	High: knowledge regarding the dynamics of animal diseases, design of the software to assess and monitor the diseases	Clear perception of the objectives to be achieved; Strategic partnership with ministries and public organizations but with difficulties in defining common objectives	Shared influence on innovation: ministries defined the health surveillance policy, public organizations are adapting the method proposed by the researchers
Support for the innovation process	Recycling of organic residues	Low: researchers diagnosed current residue management practices and actors' strategies; organized workshops to co-design scenarios	No clear perception of the objectives to be achieved: researchers proposed a process to co-design with the actors several pathways to action, the researchers decided not to guide the innovation process.	Leading influence on innovation: the main actors took the strategic decisions regarding changes in the recycling value chain without the participation of the researchers
	Integrated water management	Low: researchers diagnosed current water and crop management practices, conducted experiments on new agricultural practices, organized workshops to formulate rules for collective water management	No clear perception of the objectives to be achieved at the beginning: a wide range of options were proposed to solve the problem of water management including new agricultural practices and new crops	Leading influence on innovation: the municipality and the farmers' organizations oriented the process with the support of researchers
	Wine geographical indications	Low: researchers diagnosed current wine production, proposed new standards and technologies, organized workshops	Clear perception of the objectives to be achieved: Regular and in-depth interactions with actors to orient the innovation process	Leading influence on innovation: the farmers' organizations and the public organizations took control of adapting the standards and organizing the wine value chain
Open innovation	Pl@ntNet	High: design of software application, control over the database	Support for innovation with no clear perception of the products to be produced; Regular and in-depth interactions with actors through network coordination	Shared influence on the innovation process: improved user capacity to use the software in order to design a range of tools for diverse objectives

production of outputs, outcomes and the overall process due to their central role in knowledge and technology production. This research model appears to be especially suitable when the purpose of innovation is mainly to act on the biophysical environment and when major interactions with a large set of actors are not required, nor in-depth changes in their practices to achieve outcomes and catalyze impacts. To be successful, this intervention model requires the definition of a clear strategy for implementing research from its inception, strong institutional and political support, a strong partnership with a few strategic actors, adequate funding mechanisms, and training of actors involved in the use of scientific knowledge or technologies. This model is usually found where relatively simple problems are addressed or where actors can solve problems mainly by changing the “hardware” dimension of innovation (Patton, 2011).

3.4.2. Second model: co-design of innovation

The fonio huller case (in which a hulling machine was designed and built in West Africa) and the farm-level manure management program (in which new practices were designed to produce and use organic manure at the farm level in Burkina Faso) are both good illustrations of this “co-design of innovation” model (Table 3). On the basis of our case studies, this intervention model appears to us to be particularly suitable for the design of new farming systems or new equipment. In this model, the researchers had a clear initial perception of the objectives of the innovation process but were less certain about how to achieve them because other factors had influence over the innovation process. Consequently, the researchers had limited control over the production of outcomes. In the cases which relied on this intervention model, knowledge was shared among many actors, including farmers, NGOs, firms and advisory services, and the objectives, resources and constraints of the innovation partners had to be fully taken into consideration. Therefore, the production of knowledge useful for action and the design of new technologies required using a participatory approach involving co-learning processes and the co-production of outputs and outcomes. To be successful in applying this intervention model, the researchers and their partners had to implement an adaptive and flexible strategy able to build a high level of trust among partners, and had to pay special attention to strengthening the capacity to innovate of all the actors involved. This research model is suitable for complex situations in which all the actors have the possibility of exercising significant influence over the innovation process but need to work together, as Kline and Rosenberg (1986) showed for their chain-linked model.

3.4.3. Third model: support for the innovation process

The case of wine geographical indications “Vales da Uva Goethe” in Brazil and the case of organic residue recycling in Reunion Island (France) are both good illustrations of this “support for the innovation process” model (Table 3). In this model, actors other than researchers lead the innovation process by defining the objectives and the strategy to achieve them. In cases relying on this intervention model, the researchers were either not able to control the production of outcomes or decided voluntarily to let the other actors make their own choices independently. The role of scientific knowledge varied because what really matters here is the production of knowledge by the lead actors (non-researchers) of the innovation process. The main function of the research community in this model is to provide support to the actors involved in the innovation process, enabling them to formulate innovative solutions to problems on their own through effective learning processes. Such support may include co-production of knowledge, brokering activities and capacity strengthening in many different forms, adapted to a diversity of unexpected internal and external events that may occur during the innovation process. This research model is useful in situations of complex problems involving many stakeholders with unpredictable interactions that may take place during the innovation process. Consequently, many unexpected outcomes and impacts can

emerge in such a vortex-like process (Akrich et al., 1988).

3.4.4. Fourth model: promotion of open innovation

The Pl@ntNet case, in which a mobile phone application was developed to provide visual aid for plant identification is the only one of the 13 case studies that illustrates the “promotion of open innovation” model (Table 3). In this model, the researchers had a clear perception of the outputs to be produced but the outcomes and the potential impacts were open or unpredictable. Scientific knowledge played a critical role and the researchers designed a large part of the technologies. However, the researchers had to interact with a wide diversity of actors to jointly adapt these technologies for different purposes within a process largely led by other actors. This model of research intervention required major investments in scientific knowledge production and technology design, a flexible strategy to interact with different partners and to seize unexpected opportunities, and, in addition, clearly defined intellectual property rights. This research model appears to be particularly appropriate when other actors have well-developed capacities to experiment and to innovate in specific sectors, such as the digital economy, and agree to share knowledge and risks freely (Chesbrough, 2003).

4. Discussion

The ImpresS evaluation methodology effectively takes the lid off the black box of the contribution of AR4D to impacts. In the 13 case studies analyzed, researchers contributed to a wide range of both expected and unexpected impacts in the perception of the actors engaged in the innovation process. These impacts emerged over the long term, from 10 to 30 years as others scholars have shown (Kristjanson et al., 2009). Consequently, and as we did in our study, research impact assessment needs to go beyond the horizon of a research project or program logic to encompass clusters of projects contributing to the same innovation trajectory (Douthwaite and Gummert, 2010), even including other interventions that do not involve research but which may help address the problem identified by the actors (Joly et al., 2015; Alston et al., 2009). If not adequately addressed, this divide between short-term project-based planning and project-based research funding practices, on the one hand, and the long-term nature of research and generation of impacts, on the other, may contribute to a “culture of promised impacts” rather than a “culture of impacts” within agricultural research institutions (Leeuwis et al., 2017). This culture of promise translates into announcements of ambitious and unrealistic impacts instead of plausible and achievable impacts on targeted populations or sites.

We also identified a diversity of intervention models through which research may contribute to impacts which go beyond the two classical models – the transfer of knowledge and technology model and the systemic model to support learning processes (Hall et al., 2003; Touzard et al., 2015). Our contribution to this ongoing debate and quest for effective modalities of spurring innovation consists of proposing four archetypal research intervention models. These models describe the various types of interactions that can occur between researchers and other actors. The nature of these interactions depends on variables such as the importance of scientific knowledge in the innovation process, the researchers' perception of the objectives to be achieved on the basis of strategic partnerships, and the role of other actors as contributors to, or leaders of, the innovation process. Because the results are based on a limited number of case studies, we cannot unequivocally affirm that we have covered all the diversity of the situations concerning AR4D and thus our classification may need further refinement.

Nevertheless, the research intervention models we propose are in line with the description of research interventions analyzed in the innovation models for the industrial sector (Tidd, 2006), even though there are some key differences. First, our models focus on public agricultural research and its contribution to innovation while Tidd's work focuses on research conducted both by public organizations and private firms that can undertake internal research activities. Second, the

“support for the innovation process” model is not documented in the literature concerning the industrial sector. This is most certainly because of the specific characteristics of the agricultural sector, which include many actors with limited resources who absolutely need to collaborate to innovate. In fact, in the agricultural sector brokering functions are fundamental to support innovation (Leeuwis et al., 2017) and research may perform such a function. Third, the “open innovation” model is less frequently found in the agricultural sector even though current debates regarding open data and open access processes may change the situation significantly for the research community in the future.

Such research intervention models are also in line with other recent studies in the agricultural sector. On the basis of an analysis of 32 cases studies, Matt et al. (2016) identified four impact pathways for research to generate impacts based on two main variables: the “level of co-production of knowledge” and the “level of transformation of the user sphere” as a result of research activities. They highlight in particular the role the researchers may play as key initiators of intensive transformation and the importance of strong collaboration in long-term research programs. For their part, Douthwaite and Hoffecker (2017) identified three overall impact pathways that summarize how agricultural research may generate impacts: the public policy impact pathway, the technology impact pathway, and the capacity development impact pathway. For each pathway, the nature and intensity of interactions between the researchers and other actors are different. However, the authors support the idea that each research program willing to effectively contribute to impacts needs to address all the three pathways. In fact they did not focus on their analysis on the different research intervention models. While the conclusion of these two studies are consistent with our results, we suggest that there is a need to lay more emphasis on how research activities are organized and on the conditions required to contribute to impacts depending on the problem to be solved and on the capacities of other actors to interact with the research community or to orient research.

Still in line with these two studies, our results also show that the research community needs to learn how to manage complex and largely unpredictable innovation processes (Clark and Dickson, 2003) and to develop methods to conduct research activities based on impact pathway approaches. This implies a clearer understanding of and attention to (i) the level of control that researchers are able or willing to exert, and (ii) the strategies and resources of other actors, or needed by these actors, to be able to effectively lead the innovation process. To understand and learn how complex interventions contribute to impacts, researchers, their partners and donors need to develop a reflexive monitoring and evaluation system that goes beyond project implementation (Douthwaite and Hoffecker, 2017) by taking into account the evolution of interactions between the actors in the innovation system (Ekboir et al., 2017). In addition, we suggest that the research community should strive to identify alternative scenarios for achieving impacts during the design and inception stage of interventions. Structuring research with the help of plausible and coherent theories of change is increasingly being emphasized by donors and public agencies in order to adequately assess research activities over the long term (Joly et al., 2015; Douthwaite and Hoffecker, 2017; Thornton et al., 2017).

5. Conclusion

This article presents the main findings of the application of a participatory impact evaluation methodology developed by CIRAD and applied on 13 case studies, representing different innovation processes in agricultural research for development. It reveals diverse innovation processes based on the actors' perceptions and the large diversity of impacts identified when participatory methods are used. It also shows that research contributes to impacts by mobilizing different models of intervention. Two important lessons for AR4D can be drawn from this analysis.

First, we showed that AR4D researchers effectively contribute to impacts by performing a diversity of functions. Researchers produce outputs and, in addition, may play the role of change agents and may participate in the production of outcomes. Therefore, research institutions need to recognize and analyze this diversity of functions performed by researchers, looking beyond the production of scientific knowledge, the design of new technologies and publication in peer-reviewed journals. There is also a pressing need to understand when and how research teams rather than individual researchers should fulfill these functions.

Second, our results highlight the need to rethink research management when funding is mainly project-based. In developing countries, it is difficult to mobilize funding mechanisms that enable the implementation of medium- and long-term research and development projects that may effectively contribute to impacts. Donors tend to fund short-term projects and expect tangible short-term impacts. The challenge is therefore to develop effective funding mechanisms that enable continuity in the implementation of research and development projects. In a more practical approach, the research community needs to learn how to design or take advantage of clusters of projects embedded in innovation pathways to sustain their activities over a long timeframe. This goal calls for a long-term commitment for certain research themes and with stable partnerships. It also requires a monitoring and evaluation system which takes the uncertainty in funding mechanisms into account and is able to provide information to strategically adapt activities accordingly.

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Appendix A. Supplementary data

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References

- Akrich, M., Gallon, M., Latour, B., 1988. A quoi tient le succès des innovations? 1: L'art de l'intéressement; 2: Le choix des porte-parole. Gérer et Comprendre. Annales des Mines 11 & 12 (4-17 & 14-29).
- Alston, J.M., Pardey, P.G., James, J.S., Andersen, M.A., 2009. The economics of Agricultural R&D. *Ann. Rev. Resour. Econ.* 1 (1), 537–566.
- Baron, G., Monnier, E., 2003. Une approche pluraliste et participative: Coproduire l'évaluation avec la société civile. *Inf. Soc.* 110, 7.
- Barret, D., Blundo-Canto, G., Dabat, M.-H., Devaux-Spatarakis, A., Faure, G., Hainzelin, E., Mathe, S., Temple, L., Toillier, A., Triomphe, B., Vall, E., 2017. Guide méthodologique Impress: Évaluation ex post des impacts de la recherche agronomique dans les pays du Sud. CIRAD, Montpellier, France 96 p. ISBN 978-2-87614-731-7. [10.19182/agritrop/00005](https://doi.org/10.19182/agritrop/00005).
- Breumier, P., Ramarosandrataina, A., Ramanantsoanirina, A., Vom, Brocke K., Marquié, C., Dabat, M.H., Raboin, L.M., 2018. Evaluation participative des impacts de la

recherche sur le riz pluvial d'altitude à Madagascar de 1980 à 2015. *Cahiers Agricult.* 27 (1) (9 p).

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D., Jäger, J., Mitchell, R.B., 2003. Knowledge systems for sustainable development. *PNAS* 100 (4), 8059–8061.

Chesbrough, H., 2003. Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business School Press Books, Boston.

Clark, W.C., Dickson, N., 2003. Sustainability science: the emerging research program. *PNAS* 100 (14), 8059–8061.

Colinet, L., Gaunand, A., Hocdé, A., Joly, P.B., Lemarié, S., 2013. Une approche multi-dimensionnelle de la mesure des effets de la recherche publique agronomique: le cas de l'INRA. In: Glassey, O., Leresche, J.-P., Moeschler, O. (Eds.), *Penser La Valeur D'usage Des Sciences*, pp. 49–76.

De Janvry, A., Duster, A., Sadoulet, E., 2011. Recent Advances in Impact Analysis Methods for Ex-post Impact Assessments of Agricultural Technology: Options for the CGIAR. University of California, Berkeley.

Donovan, C., 2011. State of the art in assessing research impact: introduction to a special issue. *Res. Eval.* 20 (3), 175–179.

Douthwaite, B., Gummert, M., 2010. Learning selection revisited: how can agricultural researchers make a difference? *Agric. Syst.* 103 (5), 245–255.

Douthwaite, B., Hoffecker, E., 2017. Towards a complexity-aware theory of change for participatory research programs working within agricultural innovation systems. *Agric. Syst.* 155, 88–102.

Douthwaite, B., Kuby, T., van de Fliert, E., 2003. Impact pathway evaluation: an approach for achieving and attributing impact in complex systems. *Agric. Syst.* 78 (2), 243–265.

Ekboir, J., 2003. Research and technology policies in innovation systems: zero tillage in Brazil. *Res. Policy* 32 (4), 573–586.

Ekboir, J., Blundo, Canto G., Sette, C., 2017. Knowing what research organizations actually do, with whom, where, how and for what purpose: monitoring research portfolios and collaborations. *Eval. Program Plan.* 61, 64–75.

Ferré, T., Medah, I., Cruz, J.F., Dabat, M.H., Le Gal, P.Y., Chtioui, M., Devaux-Spatarakis, A., 2018. Innover dans le secteur de la transformation agroalimentaire en Afrique de l'Ouest. *Cahiers Agricult.* 27 (1) (7 p).

Foray, D., Mowery, D.C., Nelson, R.R., 2012. Public R&D and social challenges: what lessons from mission R&D programs? *Res. Policy* 41 (10), 1697–1702.

Habermas, J., 1984. The Theory of Communicative Action. Beacon Press, Boston.

Hall, A., Rasheed, Sulaiman V., Clark, N., Yoganand, B., 2003. From measuring impact to learning institutional lessons: an innovation systems perspective on improving the management of international agricultural research. *Agric. Syst.* 78 (2), 213–241.

Horton, D., Mackay, R., 2003. Using evaluation to enhance institutional learning and change: recent experiences with agricultural research and development. *Agric. Syst.* 78 (2), 127–142.

Joly, P.B., Matt, M., 2017. Towards a new generation of research impact assessment approaches. *J. Technol. Transfer.* <http://dx.doi.org/10.1007/s10961-017-9601-0>.

Joly, P.-B., Colinet, L., Gaunand, A., Lemarié, S., Larédo, P., Matt, M., 2015. Évaluer l'impact sociétal de la recherche pour apprendre à le gérer: l'approche asirpa et l'exemple de la recherche agronomique. *Gérer et Comprendre. Ann. Min.* 122 (4), 31–42.

Kline, S.J., Rosenberg, N., 1986. An overview of innovation. In: Landau, R., Rosenberg, N. (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic. National Academy Press*, Washington, pp. 275–305.

Kristjanson, P., Reid, R.S., Dickson, N., Clark, W.C., Romney, D., Puskar, R., Macmillan, S., Grace, D., 2009. Linking international agricultural research knowledge with action for sustainable development. *PNAS* 106 (13), 5047–5052.

Leeuwis, C., Schut, M., Waters-Bayer, A., Mur, R., Atta-Krah, K., Douthwaite, B., 2014. Capacity to innovate from a system CGIAR research program perspective Penang, Malaysia. In: CGIAR Research Program on Aquatic Agricultural Systems. *Program Brief: AAS-2014-29*.

Leeuwis, C., Klerkx, L., Schut, M., 2017. Reforming the Research Policy and Impact Culture in the. Integrating science and systemic capacity development. *Global Food Security, CGIAR.* <http://dx.doi.org/10.1016/j.gfs.2017.06.002>.

Matt, M., Gaunand, A., Joly, P.B., Colinet, L., 2016. Opening the black box of impact – ideal-type impact pathways in a public agricultural research organization. *Res. Policy* 46 (1), 207–218.

Mayne, J., 2001. Addressing attribution through contribution analysis: using performance measures sensibly. *Can. J. Program Eval.* 16 (1), 1–24.

Morgan, Jones M., Manville, C., Chataway, 2017. Learning from the UK's research impact assessment exercise: a case study of a retrospective impact assessment exercise and questions for the future. *J. Technol. Transfer.* <http://dx.doi.org/10.1007/s10961-017-9601-0>.

Patton, M.Q., 2011. Developmental Evaluation: Applying Complexity Concepts to Enhance Innovation and Use. The Guilford Press, London/New York. <http://dx.doi.org/10.1002/casp>.

Ridde, V., 2006. Suggestions d'améliorations d'un cadre conceptuel de l'évaluation participative. *Can. J. Program Eval.* 21 (2), 1–23.

Röling, N., 2009. Pathways for impact: scientists' different perspectives on agricultural innovation. *Int. J. Agric. Sustain.* 7 (2), 83–94.

Thornton, P., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S., Campbell, B.M., 2017. Responding to global change: a theory of change approach to making agricultural research for development outcome-based. *Agric. Syst.* 152, 145–153.

Tidd, J., 2006. A review of innovation models. In: *Discussion Paper. Imperial college, London*.

Toillier, A., Devaux-Spatarakis, A., Faure, G., Barret, D., Marquié, C., 2018. Comprendre la contribution de la recherche à l'innovation collective par l'exploration de mécanismes de renforcement de capacité. *Cahiers Agricult.* 27 (1) 13 p.

Touzard, J.-M., Temple, L., Faure, G., Triomphe, B., 2015. Innovation systems and knowledge communities in the agriculture and agrifood sector: a literature review. *J. Innov. Econ. Manag.* 17 (2), 117–142.

Yin, R.K., 2009. Case Study Research: Design and Methods, Fourth ed. Sage, Sage Thousand Oaks, CA.