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Nawalyath Soulé Adam, Ludovic Temple, Syndhia Mathé, Moïse Kwa

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Nawalyath SOULÉ ADAM
CIRAD, UMR Innovation, Université de Montpellier, Montpellier, France
nawalyath.soule_adam@cirad.fr

Ludovic TEMPLE
CIRAD, UMR Innovation, Université de Montpellier, Montpellier, France
ludovic.temple@cirad.fr

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Syndhia MATHÉ
CIRAD, UMR Innovation, Université de Montpellier, Montpellier, France and Science and Technology Policy Research Institute CSIR-STEPRI, Accra, Ghana
syndhia.mathe@cirad.fr

Moïse KWA
Centre Africain de Recherche sur le Bananier Plantain, Njombé, Cameroon
moisedekwa@gmail.com

ABSTRACT

Current socio-demographic and climate change challenges make agroecological transition in developing countries urgent. In institutional economics, the analysis of functional mechanisms referred to as "drivers of change" indicates the institutional levers for the development of agroecological innovation processes. We study the functional dynamics of the stem fragment planting ("PIF") process, a technological innovation produced by African agricultural research. Data are drawn from in-depth qualitative interviews and academic and non-academic literature. The Agricultural Innovation System (AIS) framework and the functional approach provide the conceptual and theoretical basis for this study. We use Event History Analysis (EHA) to identify functions and their dynamics. We identify three phases with incomplete functional loops. Missing functions and governance failures are the main hindrances to the success of the "PIF" technique. We thus give specific innovation policy recommendations for broader agroecological technological innovations in developing countries.

KEYWORDS: Banana Plantain, Appropriate Technology, Innovation Support Services, Event History Analysis, Developing Countries

JEL CODES: Q18, Q16, O3), B52

Developing countries' agriculture faces many challenges today (rising poverty of farmers, food insecurity, climate change, etc.) that make agroecological innovations necessary (Tibi *et al.*, 2022; Loconto, 2023; Matt, 2023). Once those innovations are created, there is at first a need for them to be used and, second, to be anchored in the national context. Third, there is a need for those innovations to evolve and expand in all the contexts in which they could be useful, integrating the adjustments due to implementation by their adopters. Those different steps do not occur in a straightforward way and sometimes require interventions from policy (Godin, 2017; Faure *et al.*, 2018; Köhler *et al.*, 2019).

In Central and West Africa, the banana plantain is a priority food source (Bakouétila *et al.*, 2016). In Cameroon, the banana plantain is not only cultivated as a single culture but it is also associated with various intercropping systems with annual and perennial crops such as coffee, cocoa, palm trees, and tubers (Dépigny *et al.*, 2019). It helps to provide an income source for farmers and to shade annual crops during their early years. Cameroon is thus the 4th largest plantain producer in Central and West Africa (FAOSTAT, 2022). Production has increased exponentially by 450% between 1961 and 2020. Most of the increase in production was achieved by exploiting newly created areas through progressive deforestation from 1961 to 1993. Between 1985 and 1993, a regional agricultural research program developed a technological innovation for plantain propagation: plants from stem fragments ("PIF") (Kwa, Temple, 2019). This technique increases the yield of plantain material a hundredfold compared to traditional methods and is simple and frugal compared to in vitro propagation (Sadom *et al.*, 2010). It rapidly spreads beyond the frontier of Central Africa to West Africa, Latin America, the West Indies, and the Caribbean. It meets the demand of small producers and nurserymen to reduce their planting costs. Not only that, but it also allows for homogeneity in the age of the plants and the time of harvest.

However, over the past decade, the absence of a regulatory framework for the certification of "PIF" plants has reduced the credibility of the technique and the closure of the *Centre Africain de Recherche sur le Bananier et le Plantain* (CARBAP) in 2017 coincided with a drop in plantain production at the national level. In consequence, producers' needs for healthy seedlings remain unsatisfied. Furthermore, there is still a lack of professionalization of nurserymen, as with the stabilization of seedlings' production and distribution outside the support mechanisms subsidized by the public authorities and by international cooperation. These three limiting factors, *i.e.*, unsatisfied demand for healthy seedlings, non-professional supply, and the lack of sanitary certification of seedling production, questions the ability of the technique to sustain itself over the long term beyond the support raised to develop it. This sustainability is needed to maintain alleviation of the cost burden for farmers, to increase their productivity, and to favor preservation of the environment.

Using the functional analysis from Technological Innovation System' literature (Hekkert *et al.*, 2007; Suurs, 2009), we question the mechanisms of the "PIF" technology process. What are they? And what are the hindrances? Is the process performant? Functions are defined as the purpose of the activities undertaken by the actors in a system (Hekkert *et al.*, 2007; Bergek *et al.*, 2008). According to the literature, technological innovation processes are characterized by the building of the system, a functional loop that requires the coordinated action of actors to strengthen the guidance of the search (orientation of the system toward a technical choice adapted to the innovation) and the advocacy coalition to support its development, market formation, and resource mobilization (Suurs, 2009). Considering the disappearance of the main actor of the technique's lobby and the absence of the regulatory framework for technique certification, we assume that, in the process, it is the weakness in forming an innovation system which hinders the success of this agricultural technological innovation. Our work hypothesis is that innovation support services (ISS) (Faure *et al.*, 2019; Mathé *et al.*, 2019), are activities which activate innovation process functions. Based on our result, we draw policy implications.

The second section presents a theoretical and conceptual framework of functional analysis. The third section then presents the materials and methods. The data were collected through a qualitative survey conducted with different categories of actors involved in the process, and the consultation of secondary sources. Our analysis combined a historical and a functional approach to identify the history and mechanisms of this agroecological innovation process.

The results and a brief discussion are stated in the fourth section. We end the article with a discussion and a conclusion. Our work highlights the hindrances involved in the process, with regard to the delay in guidance concerning the search and the lack of system building. Appropriate policy recommendations were provided and a contribution was made to the definition of functions.

Framework

Historically, innovation studies came from the need to orient policy choices by the definition of "models" or conceptual and analytical approaches, although the apparent distinction of those "models" conditions the scope of factors and actors that are under study in most of the literature on innovation (Godin, 2017). Over the last two decades, the Agricultural Innovation System (AIS) framework has increasingly been used to analyze innovation in agriculture in developing countries (Hall *et al.*, 2003; Touzard *et al.*, 2015; Casadella, Uzunidis, 2017) with the aim of designing innovation policies (Lundvall, 2007; Godin, 2017).

The AIS approach is a tool used to better understand system dynamics and performance (Bergek *et al.* 2008). AIS are the set of actors, institutions, infrastructures, and interactions interacting to bring about the development of agricultural innovation. An AIS may be a subsystem of a sectoral system or it may cross several sectors (Malerba, 2002; Markard, Truffer, 2008). This system contains all the components that contribute to, or which influence, the innovation process, and is not limited to the components exclusively dedicated to the innovation studied.

The "PIF" technology system in Cameroon can be considered as an agricultural subsystem at the intersection of the national agricultural innovation system of seed plants and the sectoral system of plantain production in Cameroon. Although "PIF" is a regional technique due to its development in a regional dedicated research center, as we study CARBAP in Cameroon we consider it to be a national IS. In addition, the "PIF" technology is frugal and does not mobilize technological artefacts from other national ISs. Cameroon is an under-industrialized country and is characterized by great dependence on the agricultural sector. Moreover, the public administration and institutions are weak (Temple *et al.*, 2017). Thus, we consider "the PIF" technology system as a national agricultural subsystem.

To analyze those systems, the most widely used approaches are structural failure analysis (Klerkx, van Mierlo, Leeuwis, 2012). Failures can be infrastructural, hard- or soft-institutional, from capabilities or from market structure. However, those approaches are static and fail to evaluate the effect of those components on the system. The use of a process perspective in addition to a structural perspective mitigate this by adding the temporal view that is needed. Indeed, since innovation is both dynamic and systemic, this perspective is relevant to study innovation by considering the synchronization of the mechanisms induced by the actors with the phases of the innovation process. Only this could help to target the moment of an innovation process when interventions should be made. Among the process perspective, historical analysis and functional analysis help to focus on what is actually achieved in the system (Klerkx, van Mierlo, Leeuwis, 2012; El Bilali, 2020) and are widely used for AIS and TIS.

Functional analysis originates from Technological Innovation System (TIS) analysis (Hekkert *et al.*, 2007; Hacking, Pearson, Eames, 2019; Gruenhagen, Cox, Parker, 2022). This method is based on functions defined as the purpose of the activities undertaken by actors in a system (Hekkert *et al.*, 2007; Bergek *et al.*, 2008). Those activities can help to support the innovation process, such as services (Faure *et al.*, 2019), vision development, or lobbying (Köhler *et al.*, 2019). The starting point of functional interactions that influence the trajectory of the process determines "drivers of change" or "motors of innovation", understood as a succession of functions producing a durable specific change in the process (Hekkert *et al.*, 2007; Suurs, 2009). The functional approach thus helps to understand the mechanisms underlying the development of innovations and to identify where and when interventions should be made (Jacobsson and Bergek 2011). It also provides a relevant analytical approach to identify the drivers and blockages of an innovation process or system (Lamprinopoulou *et al.*, 2014; Hornum, Bolwig, 2021; Verburg, Verbene, Negro, 2022).

Empirically, the recent application of the functional approach (Hermans *et al.*, 2019; Verburg, Verbene, Negro, 2022; Vermunt *et al.*, 2022) considers that the conceptualization of motors of innovation is difficult to apply in a context of vagueness on the limitation of phases, functions with a long start-up time, and separation of functions. They therefore prioritize the identification of functional loops. The presence of functional loops in an innovation process suggests that: 1) the functions are fulfilled in the process, and 2) the functions are complementary in the process to develop the innovation. With those two characteristics, the process is considered to be performant.

Indeed, the broad literature on functional analysis has only recently been applied to the agricultural innovation system, but there are still few studies in the context of developing countries (Edsand, 2019; Schiller *et al.*, 2020; Ankrah, 2021). Most of those countries, such as Cameroon, offer a context with institutional failures, structural failures of knowledge systems, and infrastructures (Temple *et al.* 2017). In this context, "PIF" is a technological innovation characterized by a long story and the intervention of various actors, but their interactions are weak. But even with this structure, the functional analysis is mobilizable, as stated by Bergek *et al.* (2008). We thus choose to mobilize the functional approach to answer the questions: What are the functional mechanisms of the "PIF" technique trajectory in Cameroon? And what are the hindrances? Is the process performant? The next section presents the data and methods we used for this study.

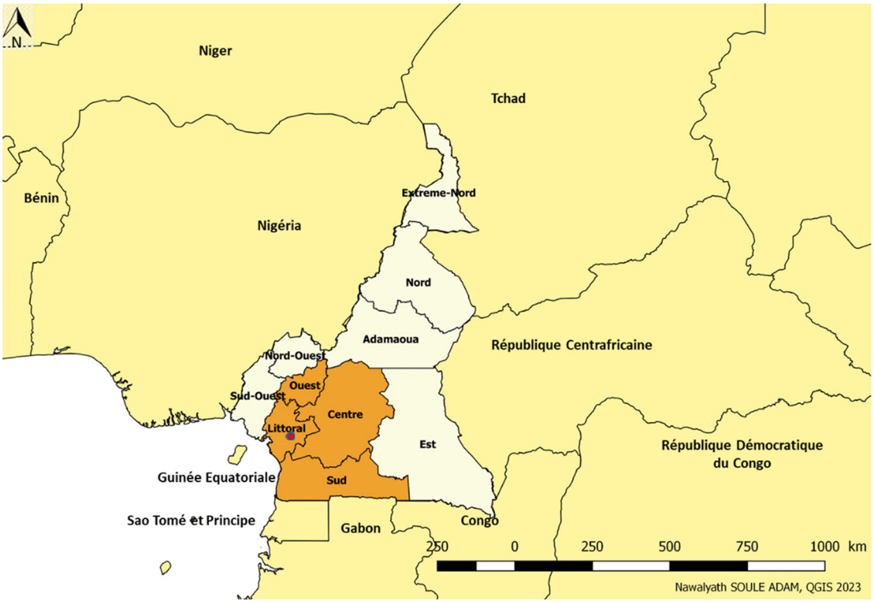
Materials and Methods

Data Collection

The data mobilized were collected through comprehensive qualitative interviews with different categories of actors involved in the process of the "PIF" technique and the collection of secondary data such as project reports, regulatory texts, and statistics on physical or digital support. Two types of interview guides were designed, one for the historical analysis and the other for the functional analysis. The historical analysis guide aimed to trace the history of the innovation and to reveal the key support services that accompanied the actors. It was given to all the actors interviewed. The functional analysis guide aimed to collect information on the support services provided. It was given to support service providers only. In both guides, to collect the performance criteria, the question was addressed to the services considered to be key services by the respondents.

The sample was constituted through a snowball approach. We carried out 43 individual interviews and one focus group among 30 respondents from innovation support service providers (private firms, ministries, and government agencies, NGOs, research institutes) and 15 respondents from innovation support service beneficiaries (farmers). We interviewed six main actors of the invention of the "PIF" technique from CARBAP. The data collection took place in the districts where the "PIF" technique has been developed (Njombe in Littoral) and is still practised (eight in total). The data collection took place from February to August 2021.

Map 1 – Regions covered by the data collection (Njombé in red)



Source: Authors, 2023

There is no ethics committee in charge of validating the socioeconomic data collection protocol in Cameroon (the only existing committee is for a clinic survey). The data collection protocol follows the European Union's H2020 programme guidelines for funded studies (European Commission, 2019). Following those requirements, we established oral consent at the beginning of each interview, notifying respondents that the data will be used anonymously and seeking their approval for the interview and recording.

Data Analysis

To reveal the factors that influenced the innovation process of the "PIF" technique, we used *Event History Analysis* (EHA) (Suurs, 2009; Suurs, Hekkert, 2009; Hermans *et al.*, 2019).

EHA is a functional approach used to associate events with functions to generate causal loops between functions. EHA is originally a microeconomic method used to study innovation trajectories within companies. However, thanks to adaptations, it is also suitable for the ex-post study of innovation systems that have a longer time horizon than that of innovation processes within firms.

EHA relies on qualitative and quantitative data such as activity reports and meeting reports to obtain results related to organizational learning. Thus, instead of data on individual actors, the data is about events in the system. It also mobilizes the construction and analysis of innovation stories. It allows us to operationalize and evaluate the functions present in a system by considering events (*cf.* Table 1). We use the definition of an event given by Suurs: "*a moment of rapid change regarding actors, technologies or institutions, resulting from the activity of actors and which has a publicly recognized importance for the system*" (Suurs, 2009). The trajectory of the process is determined by the sequence of events. In this approach, events are actually defined as intellectual constructions of the researcher, based on the categories of functions defined in the literature. It enables the realization of graphic representations: historical frieze and causality graphs.

The EHA implementation is divided into five main phases: collection of information, construction of the database, attribution of events to the functions of the system, definition of the trajectory of events, and triangulation. We used Excel 2019 to structure the distribution of events, the matching of the events with functions.

Table 1 – Description of the functions of the innovation process in the SIA perspective

Function	Description (AIS)	Example of activities
F1. Entrepreneurial activities	Creation of business opportunities from new knowledge, networks, or markets. Also includes lobbying, funding, or changing institutional structures.	Demonstrations, innovation projects, investments in new technologies
F2. Knowledge development	Creation of new knowledge in the form of research papers, reports, or physical media	Field or laboratory experiments, pilot projects
F3. Network formation and knowledge diffusion	Networking and facilitating information exchange	Creation of innovation platforms, scaling up and development of innovations, symposia, conferences, partnership building
F4. Guidance of search	The process of selecting technological options to accompany the development of the innovation. This can be done naturally or through design activities.	Expectations, promises, policy targets, standards, research products
F5. Market formation	Creation of niche markets to make innovations competitive	Market regulations, tax exemptions
F6. Resource mobilization	Human, financial, and material investments to develop innovations	Grants, investments
F7. Support from advocacy coalitions	Policy advocacy for enabling resources and institutions for innovations	Lobbies, advice

Source: Authors based on Hekkert *et al.* (2007), Suurs (2009), Chung (2018) and Hermans *et al.* (2019).

Results: Functional Dynamics During Phases

This section presents the results of the functional analysis in the first part and discusses them in the following. We present the historic (Figure 4) and the functional dynamics for each phase (Figure 2, Figure 3, and Figure 5).

During the first phase, conducted by one main actor, CARBAP, the innovation was established and brought to the scientific public. The second phase then focuses on linking networking and knowledge dissemination through participatory training, resource mobilization, and advocacy coalition, with a back and forth between these functions. The third phase starts following the unexpected closure of CARBAP, which removes from the macro-institutional framework the main actor able to guarantee technical expertise in the dissemination and development of the innovation.

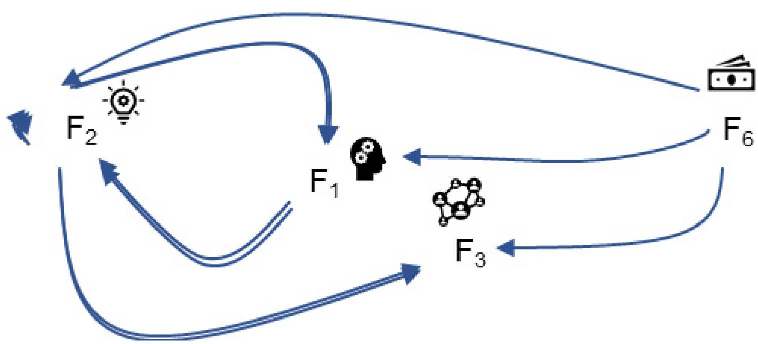
Phase 1 (1985-2000): Development of the Technique through Research Entrepreneurship

The development of the "PIF" technique can be traced back to fundamental research on plantain morphogenesis initiated at the *Institut de Recherche Agronomique et de Développement* (IRAD) in the 1980s. This research was carried out in the context of the need to increase the rate of multiplication of plantain seedlings, in order to satisfy national demand for planting material (Fongyen 1976). In 1985, experimental laboratory research began at IRAD (F2) (see Figure 2). In 1988, the development of the minisett technique, a yam propagation technology in Haiti (F2), and previous work on plantains (F2) contributed to this research (F1 and F2). From 1990 onwards, research was stepped up through a plantain research program set up within IRAD, then transformed into the *Centre de Recherche sur Bananiers et Plantains* (CRBP). The experiments carried out (F2) allowed the technique to be finalized.

A first prototyping of the technique was finalized and placed in experimentation in 1994 within the CRBP through the research department, and in natural production conditions, with a partnership of producers, thanks to public funding (Temple *et al.* 2011). In 1999, the technique was perfected and began to be promoted nationally and internationally during CRBP open days (F1, F2 and F3) and symposia (F2 and F3), and through medias. The reform of CRBP into CARBAP, as a regional organization, has mobilized more human, financial, and material resources for plantain research (F6) and has broadened the scope of opportunities for knowledge production and resource mobilization (F2, F3 and F6).

The end of this phase is marked by consultation between plantain industry players and political decision-makers.

Figure 2 – Functional loop of phase 1 of "PIF" technique trajectory, Development of the technique through research entrepreneurship (1985-2000)



Source: Authors, 2023

Phase 2 (2000-2017): Regional Dissemination by Private Entrepreneurs and Public Actors

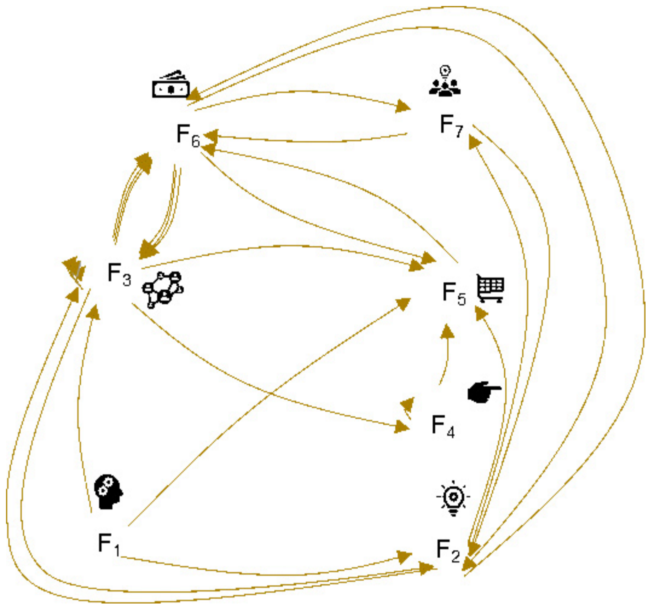
Between 2000 and 2017, CARBAP simultaneously adapted the technique to encourage its appropriation and popularize its use through training, supported by various partnerships.

The passing of the seed law in 2001 made it possible to define standards for seed activity in the installation of nurserymen (F5) and in the quality of products (F4) (see Figure 3). This law made it necessary to declare seed activity beforehand and to respect the technical itineraries subject to State control.

By 2003, CARBAP continued to monitor the adoption of the technique by farmers, by supervising students' research work. Technical datasheets are established to stabilize the conditions for reproducibility of the technological proposal and used for technology transfer through various training courses in other countries of the sub-region or other research institutions such as the CGIAR or foreign national agricultural research centers (Martin *et al.* 2019). Subsequently, ministries, national and international non-governmental organizations, and national and international research centers, were called upon or became involved in supporting this popularization by mobilizing financial, material, and human resources within the framework of partnerships. There has been an expansion in popularization internationally, not only in African countries, but also in South America, Madagascar, and the French overseas departments and territories.

The partnership between CARBAP and *Société Nationale de Développement de Cacao* (SODECAO) (F3) has made it possible to mobilize financial and human resources (F6) for the training of producers and SODECAO agents in the "PIF" technique (F3), and to sensitize producers to the cultivation of plantain in association with cocoa. The launch of technician training within the framework of the PNRVA in 2002 served as a framework for financing the training of technicians and supervisory staff in the "PIF" (F3) technique. This partnership with the African Development Fund of the African Development Bank, the Ministry of Agriculture, and CARBAP (F3), made it possible to mobilize human, financial, and material resources (F6). Diagnosis of the first phase of the Center of Rural Development Project revealed the weaknesses of the project and advocated the need to increase the capacity building component for producers at the grassroots level in the second phase, as well as the need for healthy plant material for plantain propagation (F2 and F7). The launch of the Program for the Relaunch of Plantain Production in 2003, followed by the second phase of the Center of Rural Development Project in 2004 within the framework of partnerships (F3), made it possible to mobilize resources (F6) to provide subsidies for the sale of "PIF" seedlings, thus creating a protected niche market for nurserymen (F5).

Figure 3 – Functional loop of phase 2 of "PIF" technique trajectory, Regional dissemination based on networking and resource mobilization (2000-2017)



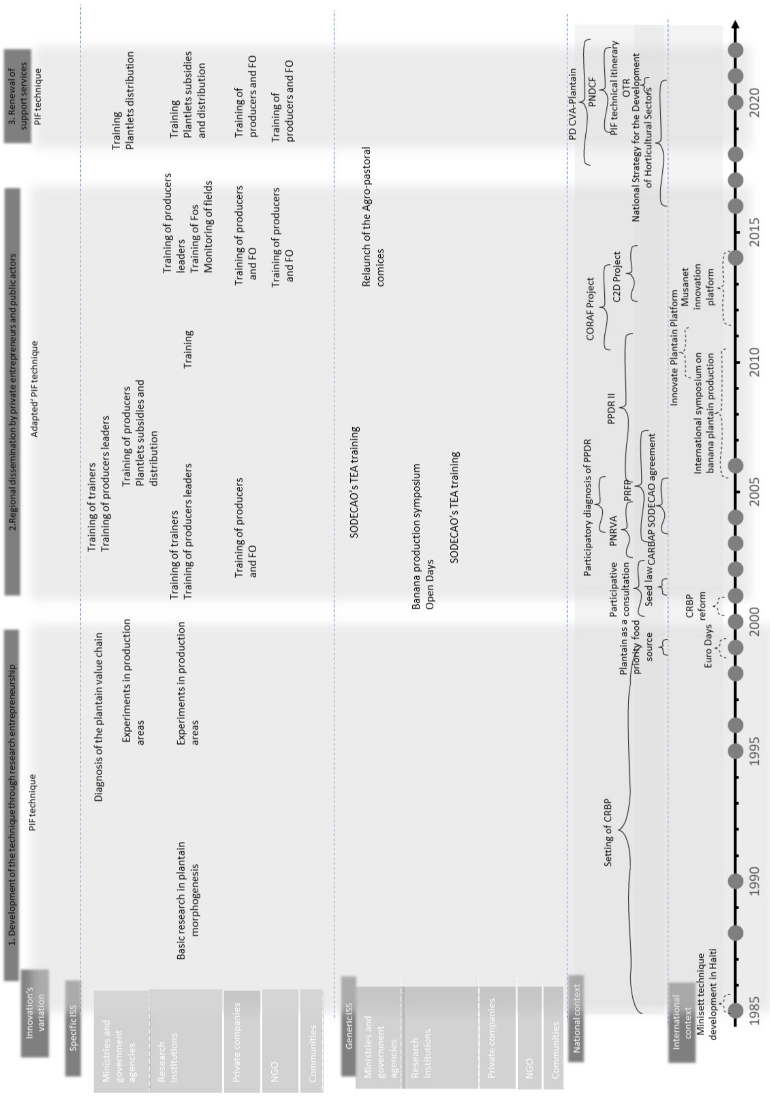
Source: Authors, 2023

The regulation strengthened an extension through market formation, research guidance, and networking for knowledge dissemination. Networking facilitated the mobilization of financial and human resources, which in turn led to knowledge generation, training, and subsidies. But at the end of this phase, the niche market is destabilized by poor governance (which is not reflected in either services or functions).

Phase 3 (2017-2022): Renewal of Support Services

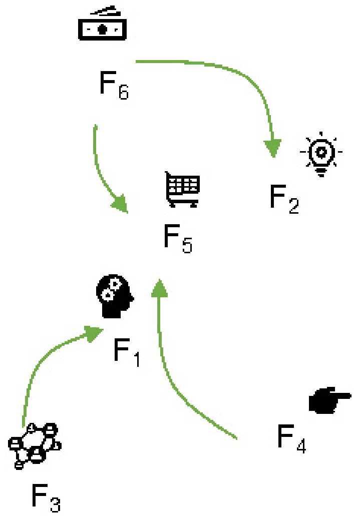
This phase starts with the closure of CARBAP, due to the ending of funding from the main donors, the EU. During this phase, on the one hand, the Value Chain Development project for plantain has been initiated to mobilize resources (F6) to document the value chain of the plantain sector (F2), to create a framework regulating the professionalization of its actors (F5). On the other hand, the training offered by public, semi-public, and private centers that does not result from networking cannot be associated with functions but contributes to the entrepreneurship of young people (F1).

Figure 4 – Historical timeline of "PIF" technology process



Source: Authors, 2023

Figure 5 – Functional loop of phase 3 of "PIF" technique trajectory, Renewal of support services (2017-2022)



Source: Authors, 2023

In the following sections, from our results, we will analyze the functional loops in the direction given to the trajectory for each phase. The discussion is centered around two major results that are presented in the next two subsections. Each section ends with policy implications. A third section presents the main contribution of the article to functional dynamics literature and also draws policy implications.

Discussion

Missing Functions and Incomplete Functional Loops Fragment the Process

Together, these results reveal the fragmentation of the functional dynamic throughout the phases of the "PIF" technology' process. In consequence, the process is not fully performant. Indeed, the functional loops present during the different phases of the "PIF" technique are not complete compared to those suggested in the literature (Suurs, 2009). Suurs (2009) identifies four types of mechanisms that translate the functional evolution of technological innovation processes described as "motors of innovation": i) Science and technology push motor; ii) Entrepreneurial motor; iii) System building motor and iv) Market motor.

During the first phase, the development of the "PIF" technique occurs through the leading of the entrepreneurial activities by the research institute, which leads to knowledge development and networking and knowledge diffusion. Then resource mobilization has strengthened networking and knowledge diffusion. Therefore, the pattern that is present is comparable to the Science and Technology Push Motor. But this did not lead to the development of laws or regulations to set an orientation for the selection of this technology. In comparison with the pattern described by (Suurs, 2009), the function of "guidance of search" is absent and there is no "loop".

During the second phase, following the passage of the Seed Law, the orientation of research led to the formation of a market, but there was no mobilization of resources to improve research and development or to capitalize on the production of knowledge on adaptations of the technique by the State. The CORAF project, for instance, was a notable experience, but limited in time. Then, within the framework of the grant programs, the mobilization of resources allowed the implementation of training and studies, but it was limited to the farmer's organizations that were enrolled in the project. The loop there is comparable to a Market Motor but is incomplete in fact since knowledge development and diffusion were impeded (Suurs, 2009).

In addition, before the Market Motor loop, the different services did not lead to the formation of a system around the plantain value chain in Cameroon. Suurs (2009) suggests that the System Building Motor should be set before the setting of the market by the Market Motor. This sequence facilitates and enables the creation of the market through a strong institutional setting.

The building of the system should have been done deliberately by interventions of actors toward guidance of search, advocacy for support, market formation, and the mobilization of resources to achieve policy measures to expand the system. But here, the multiplicity of non-coordinated objectives of research, public sector, and private entrepreneurs did not allow for the structuring of the market and momentum in the scaling up of the innovation, *i.e.*, an entrepreneurial autonomy of "PIF" production independent of public support projects, nor for a certification of the process to insure sanitary control.

In sum, even if one size does not fit all, technological innovation systems are characterized by motors of change (Hekkert *et al.*, 2007; Hacking, Pearson, Eames, 2019; Gruenhagen, Cox, Parker, 2022), but those conditions seem precisely to be lacking in the "PIF" innovation system. We thus have one major policy recommendation. It is necessary in the case of the "PIF" technique to deepen knowledge development by documenting the "experiential" or "informal" knowledge (Berkes *et al.*, 2000; Alaie, 2020) to capitalize on the learning-by-doing of various actors during the dissemination phase (Suurs, 2009). This task should be led by the research actor and include the private nurserymen or trainers that research players are wary of. This having been done, the search guidance should be strengthened by the knowledge produced and should contribute to consolidating the system.

Missing Functions, Failures in Governance, And Dependence on External Projects Weaken Dissemination in the Process

The "PIF" process represents a case of an innovation that was disseminated through support services that were offered in a deliberately collaborative approach. Indeed, while research has relied on collaborations with the State, farmers' organizations, NGOs, and other research institutions to disseminate the technique, these collaborations have often remained ad hoc and fragmented due to the short duration of projects supported by different donors, although research, State, private entrepreneurs and producers' organizations have separately offered services to producers. The research was partly relayed by the services of the Ministry of Agriculture in the training offer, leading to an increase in the number of nurseries, among small producers and throughout the national territory. Research has also positioned itself in regional transfer activities as a provider of private services due to difficulties in mobilizing its structural funding. Private nursery entrepreneurs have made their own training system independent of research and of public training services. Their targets have been medium to large-scale farmers and country programs in the sub-region. In consequence, dissemination has been pursued by different categories of actors without common objectives. Their activities made the technique less accessible to small producers, which were the initial target.

This dissemination phase also saw ineffective adaptations that damaged the technique's reputation. Some nurserymen adopting the technique made mistakes such as reusing the same planting material too often ("PIF" on "PIF"), not respecting minimum sanitary standards or the technical itinerary for plant production. Other adaptations could have potentially improved productivity and allowed private entrepreneurs to better position themselves. However, knowledge of those experimentations was not transmitted to the research institution (CARBAP). Indeed, a significant number of those nurseries' adaptations were carried out without any control of the technical itineraries by research or the State. In consequence, this organizational fragmentation of the dissemination conditions was not followed by a capitalization of beneficiaries' experiments. Furthermore, it has hindered the sanitary security of the conditions of dissemination regarding a certain number of basic rules that should be followed to avoid risks related to the possible propagation of viral diseases.

In sum, the dissemination is incomplete because it has experienced a certain instability inherent in its dependence on the opportunities of support projects that are necessary to reach producers, accompany their training, finance their equipment, and monitor their implementation of the technique with periods of growth and periods of recession. Although it led to the appropriation of the technology by producers, nurserymen, and private trainers, this dissemination phase was characterized by a multiplicity of actors' objectives, leading to a lack of consolidation of functional loops and a difficulty in activating functions related to dissemination, as discussed in the previous section. In addition, the lack of capitalization has exposed the adopters to sanitary risks. We add that the lack of knowledge development after the development of the innovation impeded the formation of an Entrepreneurial Motor during the process. The Entrepreneurial Motor is supposed to be built up after the Science and Technology Push Motor and before the System Building Motor, as stated by Suurs (2009). That should have led to encouraging private entrepreneurs to formalize their activities, and this should have led to a stronger Market Motor.

Our discussions, while preliminary, highlight the fact that failure in governance hinders the success in the dissemination phase of an agroecological technological innovation process. Those failures are the lack of coordination among actors or the exclusion of some actors and dependence on a time-framed project's interventions for dissemination of the technology. The same result was found for the development of sustainable agriculture by Schut *et al.* (2016) and Villalba Morales *et al.* (2023). We can draw two major policy recommendations.

First, we suggest that the capitalization and coordination of actors should have been institutionalized by long-term partnership agreements that would allow for the definition of a functional complementarity of support services. It could take the form of a multi-actor platform with a central role for the research actor, in the form of Public-Private Partnerships. These could, for example, be put in place to coordinate vision sharing on R&D and dissemination, formal and informal knowledge capitalization, and learning through information systems. Second, we recommend that a local institutional setting should be established to support the capitalization and other ISS in order to avoid dependence on external or publicly subsidized projects.

Contribution to Functional Analysis Literature and Policy Implications

Our results suggest that, as various ISS succeeded in activating functions, confirming our hypothesis, many ISS that were occurring or necessary during the process did not fit into the set of functions by Bergek *et al.* (2008) or Hekkert (2007) along the process.

First, the development of adaptations of the innovation needed to be documented. To mitigate this, an ISS of capitalization led by the research actor in collaboration with the private sector and the government could be implemented. Bergek (2019) has identified capitalization as a potential function that is more relevant in the context of developing country innovation systems. But Bergek's capitalization would be based on adaptations of innovations "imported" from developed countries (Casadella, Tahi, 2017). In contrast, we suggest that capitalization should be based on the production of knowledge from innovations developed and adapted locally. This could be done by using the intermediation of knowledge (Loconto, 2023) as an operational tool, for instance.

Second, the training activities offered by the private and public sectors, the networking carried out by public projects to revive the nursery trade and the plantain sector, could not be sufficiently referenced in specific functions. Indeed, the networking and knowledge dissemination functions do not correspond to the content of the activities between these actors. Further research should consider those activities as functions. For instance, the formation by training centers, secondary and high schools, and universities produce an "academization" and systematization of collective learning of the "PIF" technique. The target is no longer only the producers but it is given to any individual who has the agency to implement it. This formation enlarges actors' ability to choose in relation to the implementation of innovation. This characterizes a function of "public enrolment".

Hence, our work provides a basis to enrich the set of functions for analysis of technological innovation processes or systems in the agricultural sector.

We draw some policy implications from those contributions. The process could be revitalized by following those recommendations: i) supplying training by public and private actors, ii) decentralization of the governance of plantain programs (bringing producers closer together, reducing administrative management), iii) certification of the technical itinerary, iv) professionalization of the various actors involved upstream in the plantain value chain. The resources of the Project for the Development of the Plantain Value Chain should be used for this purpose. Indeed, once the research actor no longer benefits from the structural funding that enabled it to develop the process, it no longer has the capacity to provide information on the capitalization. However, a change in the scale of adoption of the technology linked to the creation of a market and professionalization requires, for example, that this capitalization be carried out in terms of health risk control. Further work on the link between governance and functional dynamics is therefore recommended to draw up a pertinent policy intervention scheme for systematizing agroecological innovation in developing countries.

Conclusion

The objective of this article was to identify the mechanisms involved in an agroecological technological innovation trajectory by analyzing the role of innovation support services. We based our research on two assumptions: i) Innovation support services are activities which create or activate functions in an innovation system or process, and ii) Weakness in system building explains the hindrances to the development of innovations. Both assumptions are confirmed.

The narrative of the "PIF" technique makes explicit the functional dynamics at the origin of the trajectory of this technological agricultural innovation. It shows the presence of incomplete "innovation motors": the science and technology push motor, the entrepreneurial motor, the market motor, and the absence of the system building motor. Hindrances to the formation of those motors were the delay in setting the function of search guidance and the lack of reinforcing loops, resulting from weak coordination among the system's actor interventions. The weak coordination of actors also causes failures in the governance of the dissemination phase and has led to a desynchronization in functional dynamics.

Our results strongly suggest that the analysis of the functional mechanisms is linked to the governance of the system in which the innovation occurs, especially in the dissemination phase of the case studied here. The recommendations made show the need to give the research actor the means for a central role in supporting the dissemination phase of the innovation by accompanying the development and implementation of sanitary safety standards, which are becoming necessary, considering the increased adoption of the technique in Cameroon and other countries. Applying these recommendations will improve the synchronization of functions to professionalize the emergence of a new link in the localized production of healthy plant material that responds to the need for varietal diversity in the greening of agronomic intensification, although relating functions to the structure of innovation systems requires a wider range of case studies if it is to be reliable. This is the subject of further work.

Theoretically, the contribution of this article is to specify the capitalization function in the context of developing countries, and to uncover a new function that was not included in previous work. Relatable to the context of developing countries, these functions did not appear in previous works. Empirically, the many policy recommendations made could help to shape the conception of the policies accompanying this innovation in the various countries in which it is implemented.

Indeed, the "PIF" technique has the potential to make a useful contribution to the agroecological intensification of plantain production in Cameroon and, more generally, in countries using this technology. Clearly, by sanitizing the initial planting material, provided it is planted on healthy soils, it allows a lengthening of the life cycle of the plots and thus increases the yields obtained. This increase in yield is a vector that allows markets to be supplied while reducing the increasing recourse to the cultivation of new forest plots, plantain being the first food crop used on deforestation fronts in Cameroon. This potential is nevertheless weakened by the tendency of farmers to practice monoculture and to use chemical pesticides to protect the seedling's growth, made easier by this technology.

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