Agricultural Innovation in Africa: from soil fertility to market integration. A Case study from Benin.

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ABSTRACT

In Benin, in response to the declining soil fertility and its effects on food insecurity and natural resources, farmers supported by external agents such as researchers, extension services and NGOs have developed new soil fertility management practices. In this study, we trace the history of the development of Integrated Soil Fertility Management (ISFM) initiatives in three different agro-ecological zones of Benin and highlight the different development phases and outcomes. We also present the different innovations that accompanied the use of ISFM practices, their triggers, the stakeholders involved and their role. The methodology adopted is qualitative case study research, where data were collected then analysed and finally validated by respondents. The data were collected through documents, semi-structure interviews of purposefully selected respondents and direct observation. The findings shows that ISFM practices besides being knowledge-intensive are often expensive in time and money but can raised crop yield and reduce food insecurity of the household. Some key factors for the success of ISFM initiatives had been drawn from the case studies which are: availability of technological options where soil fertility is a by-product, implication of farmers and farmers' local knowledge during the entire development of soil fertility strategies, existence of partnerships between different stakeholders with wide range of expertise (e.g. economy, ecology, social sciences) and activities (e.g. buyers, input suppliers, credit supplier, policy-makers), easy access to inputs, output and financial market. It also demonstrates that technological changes need to be combined with social and institutional changes that create an enable environment for scaling-up of innovation. Thus, it is recommended to use an innovation system-based approach and not focusing on either the production or the marketing alone, but better working on the issue as a whole.

Key words: Agricultural innovation, Integrated Soil Fertility Management, Benin, Farmers' knowledge, JOLISAA project

Table of contents

List of abbreviations

AGRA	Alliance for a Green Revolution in Africa
AIC	Association Interprofessionnelle du Coton
ARD	Agricultural Research and Development
CASE	Competitive Agricultural Systems and Enterprises
CeRPA	Centre Régional de Promotion Agricole
CLCAM	Caisse Locale de Crédit Agricole Mutuel
FCFA	Benin national currency
GDP	Growth Domestic Product
IFDC	International Fertilizer Development Centre
LSSEE	Laboratoire Sciences du Sol, Eaux et Environnement
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
PLAR	Participatory Learning and Action Research
SSA	Sub-Saharan Africa
UAC-FSA	Université d'Abomey-Calavi - *Faculté des Sciences Agronomiques du Bénin*
USAID	United State Agency for International Development
WACIP	West African Cotton Improvement Program
WUR-LEI	Wageningen University - Technology and Agrarian Development
WUR-TAD	Wageningen University - Agricultural Economics Research Centre

List of figures and tables

1. Introduction

1.1. Context of the study

In most of Sub-Saharan African (SSA) countries, agriculture is the main economic sector (TSBF 2002). Benin is no exception with an agricultural sector that contributes to 32.2% of the Gross Domestic Product (GDP) (CountrySTAT-Benin 2008), 90% of the export earning, 15% of the government revenue and 70% of the national employment (African Economic Outlook 2012). Nevertheless, in general, in SSA, agricultural productivity has been stagnating and the per capita agricultural production had fallen during the last decades (Swift & Shepherd 2007).

The quality of the soil determines the potential for agricultural development and then the capacity of smallholders to attain food security and improve their livelihood. As stated by Sanchez et al. (1997, p.1), "soil fertility depletion in smallholder farms is the fundamental biophysical root cause for declining per capita food production in Sub-Saharan Africa". Soil fertility depletion is not just about nutrient depletion but also about soil physical and biological degradation. During the last decades, soil fertility became the watchword in Agricultural Research and Development (ARD) in SSA and in the agendas of policymakers (e.g. African Fertilizer Summit in Abuja, Nigeria in 2006 and NEPAD, CAADP[1], 2003) and donors (e.g. AGRA program financed by the Bill and Melinda Gate Foundation and the Rockefeller Foundation).

The over-exploitation of land due to continuous cropping of land with no replacement of nutrients up-taken in harvest is the main reason of soil fertility depletion in SSA. In Benin, the continuous cropping of land and the decrease of fallow land area and period is due the demographic growth and the expanding cash crop (cotton) area. In Benin, it has been reported negative balance, in 1983, with a loss of 14 kilograms (kg) of Nitrogen (N), 1 kg of Phosphorous (P) and 10kg of Potassium (K) by hectare and by year (Stoorvogel & E. M. A. Smaling 1990). Van der Pol, Gogan, & Dagbenonbakin (1993) quantified the depletion of soil fertility to be 14kg N and 5kg K in South Benin.

In summary, tackling the soil fertility decline issue and favoring the investment into soil fertility is fundamental to achieve the Millennium Development Goals of reducing extreme poverty and hunger by increasing the total food production (Goal 1) and ensuring environmental sustainability by intensifying sustainably agricultural production (Goal 7) in SSA (Verchot et al. 2007; Place et al. 2003). Therefor, sustainable intensification of smallholder African farming system is increasingly being promoted for poverty alleviation (TSBF 2002; Place et al. 2003; Bationo & Waswa 2011).

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[1] NEPAD, 2003. Comprehensive African Agriculture Development Programme (CAADP). New Partnership for African Development (NEPAD). http://www.nepad.org.

Different measures and approaches had been developed to replenish the soil fertility in Africa, over the last decades. Research promoted several technologies to improve soil fertility. In the 1960s, those technologies were primary focusing on mineral fertilizer use and the classical top-down approach for technology diffusion was used. But since then, this approach in Agricultural Research and Development (ARD), in Sub-Saharan Africa received numerous critics (Spielman et al. 2009; Sumberg 2005). Indeed, whereas in many parts of the world, especially in western countries, the linear model of technology development also called the Transfer of Technology (ToT) approach (researchers develop and release the technology that will be then delivers to farmers by extension staff) generated good results and increased considerably the land productivity; this approach did not succeed in enhancing poor people livelihood in SSA (Sumberg 2005). The ToT approach does not see farmers as innovator and local knowledge is not taken into consideration during the development of the technology but only for the fine-tuning during on-farm testing. This approach succeeds well for simple technologies such as High Yielding Varieties in favorable environment. Then, from the 1980s, the focus changed toward a more biological approach to soil fertility management and the use of more participative approach. Different practices such as improved fallows developed by INRAB, the National Agricultural Research Institute of Benin, had been promoted through extension services and on-farm testing but the adoption rate remained very low. Indeed, technologies were not adapted to local constraints such as long-term land tenure right, access to organic and inorganic fertilizers, work force availability etc.

Finally, since the mid-1990s, research and development conceded that inorganic fertilizers are required to increase the productivity of African lands but as they are expensive, they need to be combined with organic matter (Vanlauwe et al. 2001). This new paradigm is called Integrated Soil Fertility Management (ISFM). This approach also acknowledges the need for a more systemic approach for agricultural innovation and for multi disciplinary (e.g. agronomy, economy, social sciences) and multi-scale approach (Swift & Shepherd 2007). In Benin, different projects dealing with ISFM were launched in different parts of the country with the aim to increase agricultural production. Through three different case studies, the objective of this research is to document and to learn from those initiatives using an Innovation System (IS) approach and to review the scaling-up issues facing those initiatives.

1.2. JOLISAA Project

This Master's thesis was carried out under the JOLISAA (*JOint Learning In and about Innovation Systems in African Agriculture*) project. JOLISAA is EU-funded, multi-institutional project started in February 2010. The goal of this project is to encompass "the lesson learnt about implementing multistakeholder approaches to innovation development, paying explicit attention to local/traditional (L/TK) in the process" in SSA. In order to have a larger idea of the situation of innovation in African agriculture and allows a cross-analysis of innovation systems in SSA, the project was undertaken in three regions of the SSA: Eastern, Southern and West Africa with respectively Kenya, South Africa and Benin as 'target' countries. The study was conducted as part of Task 2.3 of the so called Work Package 2 that consists in assessing and understanding, for beforehand selected innovation cases, how innovation processes unfold with a focus on multi-stakeholders innovation aspects, and the role of local knowledge.

This project brings together researchers and practitioners from the North and from the South. The northern team is composed of CIRAD[2], WUR-LEI, WUR-TAD, ETC[3], and ICRA[4]. The southern team is composed of UAC-FSA (for Benin), the KARI[5] (for Kenya) and the University of Pretoria (for South Africa).

The Work Package 2 undertaken in this study looks at innovation as a system (with multiple stakeholders and knowledge sources) and as a process (change of stakeholders, of their role, and interactions). Several innovation study cases were selected for in-depth study, according to several criteria. A Collaborative Case Assessment (CCA) guide designed and validated in an iterative way by the members of the project presents the common analytical framework and operational approach to favour cross-analysis between cases. The involvement of local and national stakeholders in the CCA was important as they are the one that can identify more suitable agenda for future research, practices and policy and as they are the one that can change stakeholders approach regarding innovation development.

This study focuses on ISFM in Benin as innovation case, with a focus on three locations where ISFM initiatives had been implemented.

1.3. Justification of the study

Soil fertility has a major impact on food safety and rural livelihood. In Benin, population pressure on land and the rare use of organic and inorganic fertilizers caused the depletion of soil fertility. Then, to achieve food security and to limit land degradation, there is a need for sustainable intensification of smallholder African farming system (Bationo & Waswa 2011). In this context,

[2] French research centre working with developing countries to tackle international agricultural and development issues

[3] Not-for-profit research and advisory organisation, expertise on rural development, sustainable agriculture and NRM, urban agriculture, indigenous knowledge systems, renewable energy systems and public health programmes.

[4] International Centre for development oriented Research in Agriculture, capacity-strengthening organisation.

[5] Member of the Kenya National Agricultural Research System

Beninese farmers, helped by different actors (e.g. NGO, Research institutes, and extension services) developed since the mid-1990, strategies aiming at increasing the agricultural productivity and enhancing their livelihood, through ISFM. A wide range of technologies had been developed among which the use of inorganic fertilizers such as green manure, composting, farmyard manure, planted fallow or cover crops, the management of crop residue, the establishment agroforestry system with alley farming, and the cropping system management with cereal-legumes intercropping or rotation. There is little information and documentation about the different ISFM projects and initiatives implemented in Benin with the support of external donors.

Today, the African agricultural sector is changing with the implication of new actors (NGOs, private sector), relationships (partnership private-public) and policy (Common Agricultural Policy CWA). Moreover, the main goal of Research and Development (R&D) in developing country became to *enable* rural innovation. Therefor, to achieve this goal, there is a need to understand how innovation happens and unfold. Still, very little is known about the innovation process involving multiple stakeholders and little research had been done into what each partner contributes, how these processes are initiated and unfold in different social and institutional setting, what their drivers are and how hybridization of different knowledge takes place.

Then, the ISFM initiatives in Benin are interesting case studies as they answer to the need for documenting those initiatives and also can help understanding how agricultural innovation unfolds.

1.4. Research objectives

The purpose of this study is to document the lessons learnt from (on-going) successful and failed ISFM initiatives in Benin. The specific objectives are:

-To identify the innovations developed by Beninese farmers and others stakeholders in relation to ISFM.

-To give some insight about the interaction between farmers and other actors in the agricultural sector and the contribution of those interactions on the innovation processes.

-To explore how the diver’s sources of knowledge, skills and other contributions have been combined during the innovation process, and which activities and interactions pertain to the knowledge development.

-To identify the problems and constraints (limits) for scaling-up the ISFM practices by revealing for what reasons, in which context and which manner some farmers develop practices on soil fertility or others failed.

-To propose lessons in term of practices, the underlying concepts, methodology and narratives, and in term of context, i.e. support structures (donors, national government, universities, research and development, extension agencies etc.), and mechanisms (coordination, platforms, policies) that support farmer's innovativeness.

2. Theoretical Framework

2.1. Innovation process and innovation system

During the last decade, responding to the non-large scale effect of the participatory approach, the Innovation System (IS) concept is increasingly used in Agricultural Research and Development (ARD).

Innovation is not to be confounded with invention. Mytelka (2000) defined innovation as a process by which organizations "master and implement the design and production of goods and services that are new to them irrespective of whether there are new to their competitors, their country or the world". This means that:

-Innovations may be brand-new or a combination of already existing elements,

-Innovations can bring major, minor or continuous improvement,

-Innovations can be technical, institutional, organizational, and social… (World Bank 2006)

Hence, an innovation system is defined as "a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into social and economic use, together with the institutions and policies that affect their behavior and performance" (World Bank 2006). In this definition, innovation is conceptualized in a more systemic, interactive and evolutionary way (Hall et al. 2006) (Figure 1). It is a new understanding of innovation as a process.

2.1.1. Innovation can be triggered in many ways

Triggers are factors that stimulate the innovation. It can for example be an environmental issue (decline of soil fertility), a competitive condition, a new policy (land tenure reform), or an international organization intervention.

World Bank (2006) distinguished two types of innovation trajectory. In one hand, the innovation can be *planned* or *orchestrated* and on the other hand it can be *opportunity-driven*. In the first case, innovation starts with a foundation stage, during which the government priorities some sectors or commodities, and supports them with policy and research. Then, the second stage is the expansion stage. It is when the government develops projects or programs to create linkage between the different actors of the innovation system. In the second case, we can distinguish two stages. The first stage corresponds to the moment where the private sector, helped or not by NGOs identifies market opportunities. Then, the innovation takes off and the sector became recognized by the government. Both those trajectories end with a self-sustaining innovation system. At this stage, both the public and private sector have strong interactions, favoring it ability to respond to new challenges and opportunities in a sustainable way.

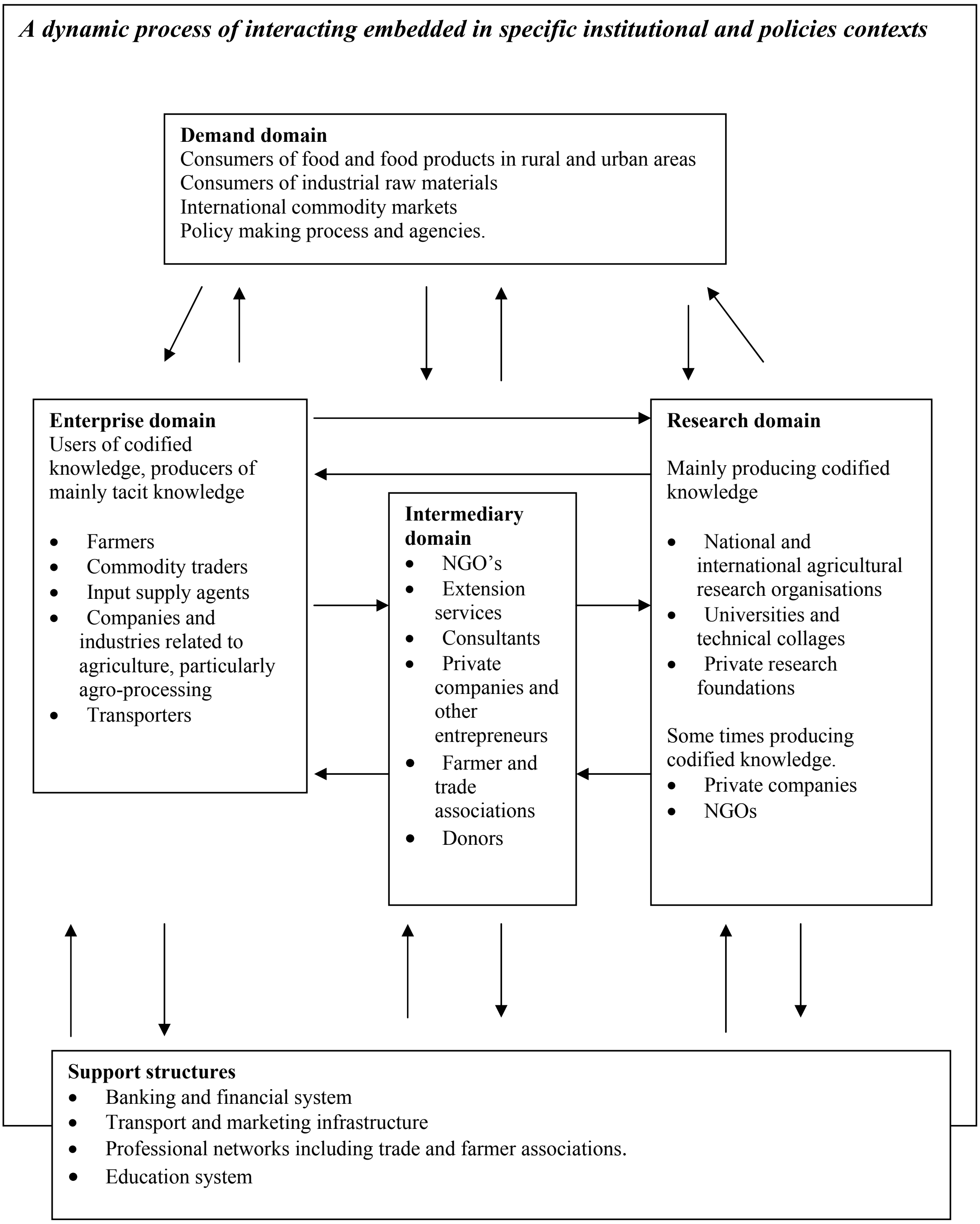


Figure 1: Elements of an Agricultural Innovation System (Hall et al, 2006 adapted from Arnold and Bell, 201)

The source of innovation and drivers of the innovation process can be the action of an individual or a small group of people but the wider use of innovation, involve many more actors and many more changes. Innovation is a multi-actor processes.

2.1.2. Innovation as multiple-stakeholder process

As mentioned by Hall et al (2006), public agricultural research is important but alone it cannot create a dynamic innovation capacity. Thus, the role of non-research organizations and civil society organization in innovation is increasingly recognized. From an innovation system perspective, innovation is understood as a process during which multiple stakeholders are involved (e.g. research, farmers, producer's organizations, NGO, input suppliers) (Figure 1). Each of these actors has a role: seeker of knowledge, producer of knowledge, or coordinator of linkage between actors (Hall 2005). Their roles may change over time, becoming more or less important, and sometime some actors can be left out (Hall 2005). Actors can be grouped into different categories according to their main activity (Figure 1).

Intermediary organizations are more and more recognized as crucial from an innovation system perspective. They sit between and connect actors in the innovation ((Kristjanson et al. 2009). They act as 'innovation brokers'. They are systemic intermediary (Howells 2006). Their role is to build appropriate linkages and facilitate multiple-stakeholder interactions in innovation.

Besides, these actors are more or less linked to each other. Relationships, as mentioned by World Bank (2006), promote interactions that in turn promote learning and innovation. Linkage is a requirement for acquiring knowledge and learning.

2.1.3. Innovation and knowledge

Innovation is the result of an interactive process of generation, diffusion and application of all type of knowledge (local and global, people's and scientific) with the aim to achieve desired social or economic outcomes (Hall et al 2006). Knowledge and information flow are multidirectional, that allow feedback loops with the aim to enhance competence building, learning and adaption (Hall et al, 2006).

Knowledge can be acquired through learning, experience and research but it becomes innovation only when it is applied (Hall et al, 2006).

2.1.4. Innovation and nurturing environment

In an innovation system, institutions play a central role. It is important to distinguish the two terms institution and organization. Organizations are for example enterprises, NGO or farmer cooperative. Institutions are as defined by Hall et al 2006 (according to Edquist, 1997) "the sets of common habits, routines practices, rules or laws that regulate the relations and interactions between individuals and groups". Then, institution determines the propensity of organizations and actors to innovate. Todays' SSA agricultural sector is rapidly changing with the implication of new actors, relationships and policies. The market becomes the main driver of technological changes. New demographic and agro-ecological pressure on farms, the liberalization of trade and regional trade integration, accompanied by the growth of private investment, and the expansion of information and communication technologies make the African context more unpredictable (Juma 2011). Therefor, more attention is needed on institutional context for research for development, as environmental context change quickly, and then requires that farmers and other stakeholders respond and adapt to those new context.

Only one policy cannot support innovation, it should be a set of policy (Hall et al 2006) and those policies should pay attention to institutions (Mytelka, 2000). For example, if the habits and practices of scientists did not change when doing participative research, they rather do ineffective research.

2.1.5. Conclusion

The development of innovation system framework led to the reconceptualization of R&D, where the linear view of technology development is view in a more systemic way where a wide range stakeholders are involved (based on the multiple source of innovation Biggs & Clay, 1981; Biggs, 1990) and where knowledge and information is not only hold by researchers (refer to the "agricultural knowledge and information system " (AKIS) developed by Röling, 1989). Therefor, innovation is understood as a process of developing "new things and ways that work".

To conclude, when using the innovation system approach, we should look at the innovation as a process of creation and application of different knowledge, triggered by external factors that include multiple types of actors and the environment (institutions and policy).

2.2. Integrated Soil Fertility Management: concept and approach

2.2.1. Soil fertility definitions and soil fertility decline

The term *soil fertility* has many definitions and is understood in many ways (Patzel et al. 2000). In its narrow sense, soil fertility refers to the soil capacity to supply nutrients to the plant in sufficient amount at the right time. Soil fertility is reduced to the soil nutrient aspects, and deals with the three major nutrients that are Nitrogen (N), Phosphorous (P) and Potassium (K). In this master thesis, soil fertility is understood as a combination of soil chemical, physical and biological factors that affect the land capacity to supply nutrients to the plant. As defined by the SSSA, (1997) , soil fertility is "the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants or crops". This definition seems more appropriate as the different practices used by farmers do not only change the nutrient status of the soil but also its structure and its biological status (e.g. the preservation of crop residues enhance the soil structure as well as its nutrient content).

Then, soil fertility decline encompasses nutrient depletion or nutrient decline (i.e. removal of nutrients greater than addition of nutrients), nutrient mining (i.e. only removal of nutrient, no addition of nutrients), acidification (i.e. decline in soil pH), the decrease of soil organic matter content, and the rise in toxic element (e.g. Aluminum) (Hartemink 2006). Thus, practices related to soil fertility encompass practices for the replenishment of the soil fertility, practices to sustain soil fertility and the ones to enhance soil fertility.

2.2.2. Evolution of soil fertility paradigms in Africa

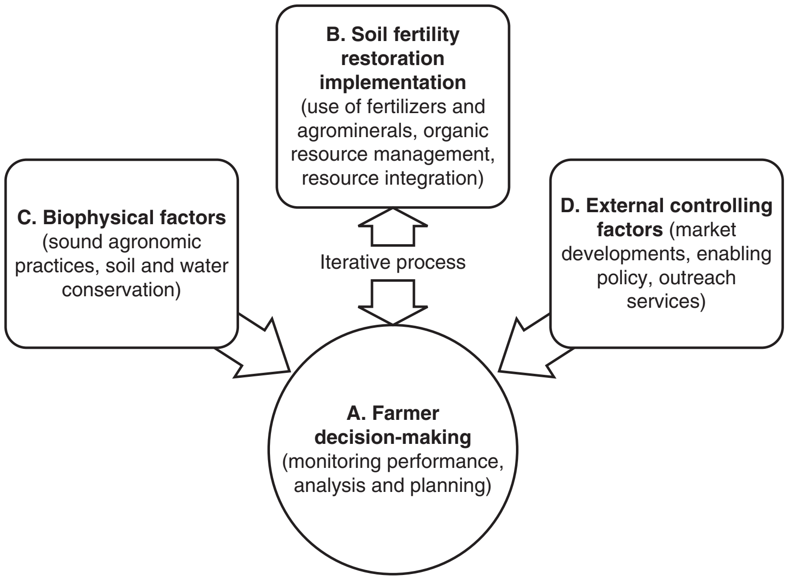
During the last three-decade, paradigms of research and development agenda on soil fertility had changed to adapt to the low adoption of improved soil fertility management practices as well as their approach to research and development (Vanlauwe et al. 2003). During the 1960s and 1970s, the first paradigm or 'external input' paradigm in tropical soil fertility research was applied. It was based on the idea that external inputs (e.g. fertilizers, irrigation) were sufficient to overcome soil fertility constraints presents in SSA (Sanchez et al. 1997). As a consequence to this paradigm, SSA's governments introduced subsidies on mineral fertilizers (Smaling 1994). This paradigm in the context of Green Revolution was successful in Asia and Latin America but the success in SSA was very little because of different reasons (IITA, 1992). De Janvry (2010) reviewed those reasons. First, natural constraints hindered the Green Revolution to be successful in Africa. Those constraints were: (a) wheat and rice are not the main crop in Africa. A higher diversity of crops are grown in Africa compared with Asia, which make it more challenging for research (b) Africa is a large continent with very different agro-ecological zones, so it requires a bunch of soil fertility management techniques (c) most of the African agriculture is rain-fed in contrary with Asia where it is irrigated. Secondly, structural constraints with the withdrawal of the state since 1980's, the lacks of agricultural extension services and the reduce capacity of agricultural research prevented Green Revolution in SSA. Also, infrastructural constraints such as the low road density and high transportation price, and the low empowerment of smallholders and weak institutions that are export oriented and not food oriented are also mentioned. According to Verchot et al., (2007), the lack of concerted effort and political willingness are additional reasons for the failure of the Green Revolution in SSA.

Then, from the mid-1980s to the early-1990s, the consequences from the application of the first paradigm (e.g. land degradation) and the abolition of fertilizer subsidies due to structural adjustment programmes (SAP), led to the development of the 'organic input' paradigm. This paradigm is based on the idea that external inputs need to be minimized or even avoided. It is also called the Low-Input Sustainable Agriculture (LISA) paradigm. The ARD focused on developing technologies that prioritized biological techniques to replenish the soil fertility, also called zero-input technologies. Living-mulch is an example of such technology. Different low input techniques were developed and tested in real situation (Versteeg & Koudokpon 1993). However, although it is undeniable that organic matter is essential to maintain soil fertility, it cannot alone prevent further removal of soil nutrients. Also, those technologies are land and labour demanding and often the access to organic resources remained limited.

Finally, Sanchez (1994) formulated the second paradigm that recognized the need to use both mineral and organic fertilizers as well as the need for improved germplasm. This paradigm recognized that organic and inorganic amendment have positive and complementary interactions, and that one cannot substitute the other (Vanlauwe et al. 2010; Buresh et al. 1997). The positive interaction between organic and inorganic fertilizers had been reported in Vanlauwe et al. (2001) study about maize in West Africa. The key complementarity between the two sources is that inorganic fertilizers aimed at limiting the losses of targeted nutrients whereas organic fertilizers by enhancing the soil organic matter support its functions. Another reason that favoured this paradigm is that using either organic or inorganic fertilizers alone is neither sustainable nor profitable nor feasible for smallholders' farmers in Africa. They are not willing to invest a lot in theirs soils as they missed insurance and worked in a rather uncertain climate. Then, using only mineral fertilizer will be too expensive and they cannot afford it. Also, as the soil organic matter is very limited in tropical soil, the use efficiency of mineral fertilizer is very low (used efficiency is kilogram of nutrient apply.ha^{-1}.kg crop $harvested^{-1}$.ha^{-1}). Therefor, they cannot only rely on the application of chemical fertilizers. On the other side, using only organic fertilizer is not really efficient in increasing land productivity. Indeed, most of the time, organic material are quite poor, and farmers need to deposit a huge amount of it, which will require labour, transportation and high investment (in animals and/or land) (Sanchez 2002).The main organic soil fertility practices in Africa according to Place et al (2003) are reviewed annexe 1.

More recently, a new approach called INRM (Integrated Natural Resources Management) was developed. It acknowledges the need for 'participative' approach and for a multiple stakeholders involvement in research and development (Swift & Seward 1994). This shift came from the recognition that farmers' decision–making process is driven by different factors (agro-climatic, socio-economic, political) (Figure 2, Bekunda, Sanginga, & Woomer, 2010). The decision (A) of restoring soil fertility and to use technologies (B) depends on the benefits on the production. The technologies (B) must fit with the biophysical (C) and socio-economic (D) context (Bekunda et al. 2010). Today, RD uses the ISFM paradigm that follows technically the second paradigm and also recognized the importance of social, cultural and economical aspects that regulate soil fertility management practices. It is a knowledge intensive process and requires that farmers obtain new knowledge and information and it also asked for continuous capacity building of farmers (Bekunda et al 2010). When using the ISFM concept, other factors are taken into account such as soil fertility, land tenure, inputs-output market, access to credit and institutional

Figure 2: Conceptual diagram of the soil fertility restoration process and the controlling factors (source : Bekunda et al 2010)



support. For doing so, organisational as well as social innovations are required. Stakeholders from the agricultural system (including input dealer, processors and traders) need to have more competences. It is a more innovation system-based approach than technology-based. Currently, the approach used to implement ISFM is the Innovation System (IS) approach. Reinforcing the relationship between the different stakeholders of the food and farming systems is necessary for effective agricultural innovation (Bekunda et al 2010).

2.2.3. ISFM approach

A gap exists between the knowledge hold by farmers and the one old by scientists about soil fertility practices and processes. Also, it seems that another gap exists between what farmers knows about soil fertility and what they can do. This part will review the ideal framework to implement ISFM in SSA, according to the literature on the subject.

2.2.3.1 ISFM is knowledge intensive: Bridging the knowledge gap with truly participative approach

Local knowledge as an entry point of agricultural innovation

Since the 1980s, it is became more and more recognized that indigenous knowledge (IK), also called traditional knowledge need to be taken into consideration for agricultural development in Africa. As mentioned by Brokensha et al. (1980) the incorporation of IK in development program is more effective than the traditional top-down approach. In 1998, the World Bank acknowledged that IK should be used as an entry point for development and that research needed to be done on local practices and knowledge. It is important in every development initiatives to understand, assess and not ignoring farmers' perceptions, knowledge and practices as it influences their decisions (Brokensha et al. 1980; Gurung 2002). Also, by assessing and considering the knowledge hold by farmers it make the development of technologies more appropriate and also favor the communication between farmers and the researchers or other interventionists (Desbiez et al. 2004).

Combining scientific and local knowledge for ISFM development

Farmers have their own understanding and knowledge about soil fertility, and constantly adapted their farming system to the changing environmental conditions (Veldhuizen et al. 1997). Their soil fertility management practices evolved over the time to fit into their farming strategies (Adedipe et al. 2004; Dawoe et al. 2012). But today, the food production per capita decreases in Africa, and traditional practices and local knowledge seems not to be able to respond to the increasing demand for food (Fairhead & Scoones 2004). Indeed, soil fertility is challenging because it is often invisible and highly variable in time and space and then asked for lots of knowledge about soil processes. Farmers have often a good understanding of the effect of soil fertility on plant growth and health and easily establish cause-effect relationships but they often lack knowledge about other hardly discernable and visible biological or chemical processes (Defoer & Scoones 2001). Different authors (e.g. Desbiez et al, 2004 in Nepal and Dawoe et al, 2012 in Ghana) in their study about soil fertility shown that on one hand, scientists hold knowledge about soil fertility biological, physical and chemical processes and have access to worldwide experiences and knowledge and on the other hand, farmers have knowledge about local conditions and context specific knowledge useful to adapt the practices to the local environment. Then, farmers' knowledge and scientists' knowledge are both important for the development of soil fertility technologies and strategies and should be linked to enhance sustainable agricultural development (Asenso-Okyere & Davis 2009). Besides, they demonstrated that local extension services could play a role and develop the link between the two types of knowledge.

Need for a truly participative and iterative approach

Different researchers developed frameworks to implement ISFM in Africa using participative approach. Ramisch et al. (2006), in Kenya, used a learning approach that builds on traditional knowledge more particularly 'folk ecology' knowledge and the knowledge hold by outsiders. The approach was based on community learning with the use of collective and individual experimentations and farmers-researcher meetings with the aim to empower and build farmers capacity. Dawoe et al (2012) in Ghana argued that as scientific and local knowledge are complementary and in order to facilitate the integration of both type of knowledge and to support farmers' perspectives in national policy, it is important to use a "truly participative, gender sensitive, collaborative and capacity-building approaches ". Beside, Engel, (1997) reported that approaches that tried to integrate scientific and local knowledge about soil fertility should create space to share different knowledge and experiences and favor joint learning and mutual respect.

One factor mentioned by several authors about the effectiveness of joint learning between different actors and knowledge is the quality of interaction and relationships between those actors (Dawoe et al, 2012). The interaction of scientists with farmers gives them the proper understanding of farmers' view and perspectives. On the other side, farmers by working closely with scientists can acquire new skills related with experimentation and methods (Defoer & Scoones 2001). In their study in Mali, Ethiopia and Zimbabwe, Defoer and Scoones (2001) demonstrated that interactive learning approaches can benefits to both part.

Scaling-up research and experimentation findings

The issues of scaling-up the findings of small-scale participative approach linked with ISFM in Africa are multiple. One of the first aims of participative approach is learning. Learning being a long-term process, it will be too costly to carry out participative projects in all villages. Then, to ensure the scaling-up of effective participative learning project in village, the farmers that participated in such should be formed to help neighboring farmers (Defoer and Scoones, 2001). In their study in Mali, Defoer and Scoones (2001) shown that first participants of the project now shared their new knowledge by actively initiated meeting and field days with surrounding villagers. This process is called spin-off effect and developing an effective farmers network with neighboring villages can favor this process (Defoer and Scoones, 2001). PLAR approach requires time and efforts but it also requires that the persons involved in the approach are willing to changes their classical approach and methods and be able to work closely with farmers.

ISFM as mentioned earlier is not only about knowledge gap about soil fertility. Other factors hinder the scaling-up of such initiatives. ISFM initiatives impact varies according to it proper fitting into farming system as well as its potential to increase farming profitability (Sanginga & Woomer 2009). In the study of Nederlof & Dangbégnon (2007), the knowledge on soil fertility management practices was not the only bottleneck of agricultural development. It appeared that the marketing of agricultural production, the access to credit, the security of land use, the timely access to fertilizer and the effectiveness of extension services are the limiting factors that hinder the adoption of more sustainable soil fertility management practices to larger audience. The context in which farmers are embedded is not favourable for any further development. Settle & Garba (2011), mentioned that increasing farmers production without paying attention to the local context and the marketing opportunities is pointless and concluded that the understanding of how farmers can access credit, how to develop alternative credit scheme and how to access more remunerative market is as important as learning about soil fertility building. Also, not only the link between farmers and scientists should be strengthened but also their relationships with other stakeholders that support marketing, cooperative, processing and microfinance management in order to facilitate farmers-led agricultural innovation (Bekunda et al. 2010).

2.2.3.2 Enhancing profitability: access to input supply, produce and financial market

Access to output market

The integration of smallholder farmers into remunerative output market is one of the solutions for them to get out of the poverty traps and use sustainable soil fertility management practices (Sanginga & Woomer 2009; Bekunda et al. 2010). Often, the major bottleneck to the adoption of ISFM practices is the lack of access to remunerative market for surplus production and sales (Sanginga & Woomer 2009). Tiffen et al. (1994) demonstrated that farmers with better access to profitable market invest more in farming production tools. Rolling (2009) shown that the increase of cocoa prices (from 40% to 70%) in Ghana had led to the doubling of the national production. In the case of Nigeria, farmers were more willing to invest in chemical fertilizers when they did not have to compete with subsidies grains. In order to be effective, the integration of farmers to market should be combined with investment in human capital (Bingen et al. 2003). In Kenya, a project called Maize Marketing Movement, shown that forming farmers to collective actions enhanced the success of marketing initiatives (Woomer 2002). In Zimbabwe, a program combining farmers' training about the use of rhizobial inoculants, soil fertility technologies and soybean processing with actions to facilitate the access to improved soybean seeds, and to link them with marketing opportunities had led to the involvement of 50 farmers in 1996 to over 10,000 in 1999 (Mpepereki et al. 2000). In Southern Africa for example an extension program focusing on pigeon pea production as multiple purpose legume aimed at improving the links among producers, researchers, buyers and input suppliers. The action of industrial enterprises, in coordination with NGO and government seek to facilitate farmer access to input and improved seeds. This program led to the wide adoption of pigeon pea intercropping with maize in the area (Snapp 2004). Then, besides training and experimenting new soil fertility management practices, farmers should be effectively linked with other stakeholders of the food and farming system in order to make those practices more remunerative and then economically viable (Sanginga & Woomer 2009; Bekunda et al. 2010).

Access to input market

Input access is as important as output market access for limiting soil fertility decline in SSA. In the ISFM concept, inorganic fertilizers are essential. Unfortunately, chemical fertilizers in SSA are expensive and rarely available on time and amount. Even if African farmers are well aware of their importance and role in limiting soil fertility decline and enhancing yield, they rarely apply them in the right amount at the right time because of the cost, the low and variable returns, the lack of credit access and the bad delivery (Sanchez et al. 1997). The fertilizers available are in majority imported, which increases the price at which farmers can obtain them. The market led extension approach is used to facilitate farmers' access to input, output and financial market and provide incentives to push farmers to further invest in soil fertility (Kelly et al. 2003). This approach seeks to connect farmers, input dealers, and potential buyers and provide necessary tools and knowledge about soil fertility management to farmers.

The **access to rural credit**, savings and insurances are also important to spread the positive effect of ISFM (Sanginga & Woomer 2009).

To sum-up, the supply of farm input as well as the access to remunerative market and financial market can stimulate the adoption of sustainable farming practices including the one linked with soil management (Lerman 2001; Reardon et al. 1997; Diao & Hazell 2004). Efforts should be made along the entire agricultural value chain from the input supply to the crop production and finally the produce marketing (Sanginga & Woomer 2009).

2.2.3.3 Policy and Institutions

Policy and institutional support are also required for the scaling-up of ISFM practices among smallholder's farmers in SSA. Governmental policy should favour the link between all stakeholders of the food and farming systems, and support the creation of alliances and partnerships. Policies that could favour the dissemination of ISFM should pay attention to farmers' access to farm input and output market, addresses the issue of unstable prices and high costs of transportation and finally encourages the development of strong producer organization.

It is not relevant to just increase the agricultural production but other aspects of economic development should be taken into account. Alternative employment opportunities, roads, access to markets and price differentials are also factors that should be gain attention. Unless, those aspect change, planning and hoping for an increase of food production will have no mean.

3. Methodology

In this chapter, the methodology and the methods used in conducting this study will be described. First, the chapter presents the three study areas. Then, it explains the study design, the research activities and process. Following, the methods and tools to collect data will be reminded. Finally, the last part of this chapter will explain how the collected data were analysed and reported.

3.1. The study areas

The study was carried out in three locations in Benin, respectively: Ifangni district, Dassa-Zoumè district and Kouandé district (Figure 3). The different characteristics of the three study areas are reviewed Annexe 2.

3.1.1. Banigbé village - Ifangni district– Plateau region

One of the locations selected for the study was Ifangni district in the region of Plateau, in the southwest Benin. Ifangni has a border with Nigeria and its closed to Porto Novo (the administrative capital of Benin). The district covers a small area of approximately 242 km^2 and has a population estimated of 99 050 inhabitants (INSAE 2012). The population density is high with approximately 400 inhabitants per square kilometres. The inhabitants belong in majority to the ethnic group called *Yoruba*. The languages spoken are *Fon* and *Yoruba* and the main religion is Islam.

The rainfall has a bimodal pattern. The long rainy season starts in March and finishes in July and the short rainy season occurs from September to November. The mean annual rainfall is about 1200 mm (Figure 4). The climate is favourable to the production of two to three different crops per year.

Two main types of soil can be distinguished in the district, which are, according to the local classification and the scientific classification:

-'*Ayigbavè*' or '*Tchakolè*', called ferralitic soils or 'terre de barre". They are reddish, deep, and with a low water retention capacity (Azontondé, 1991). The texture is sandy loam.

-'Ayigbayou' or 'Atanyigba', called hydromorphic soils. They are dark, deep, with good water retention capacity and more fertile than red soils. The texture of the soil is loamy.

The area is flat with light slope. Rivers and swamps surrounding the district allow the practice of growing off-season vegetables and install nursery. Ifangni is located in the Guinea-Congolian Zone which is characterized by a mosaic of forests and savannas (Wezel et al. 2000).

Agriculture is the main source of revenue for 70% of the population. The agriculture is mostly rain-fed, meaning highly dependant on climate conditions. Only vegetables produce in low land are irrigated which allow the production of counter-season vegetables (during the dry season). The irrigation of vegetable is manual with the use of watering can and some farmers' organizations are equipped with pump motor.

Very few farmers use a tractor to prepare the soil; most of them still use rudimentary tools (such as hoes and machetes). The farming techniques are done by hand, and then require work force, energy and money.

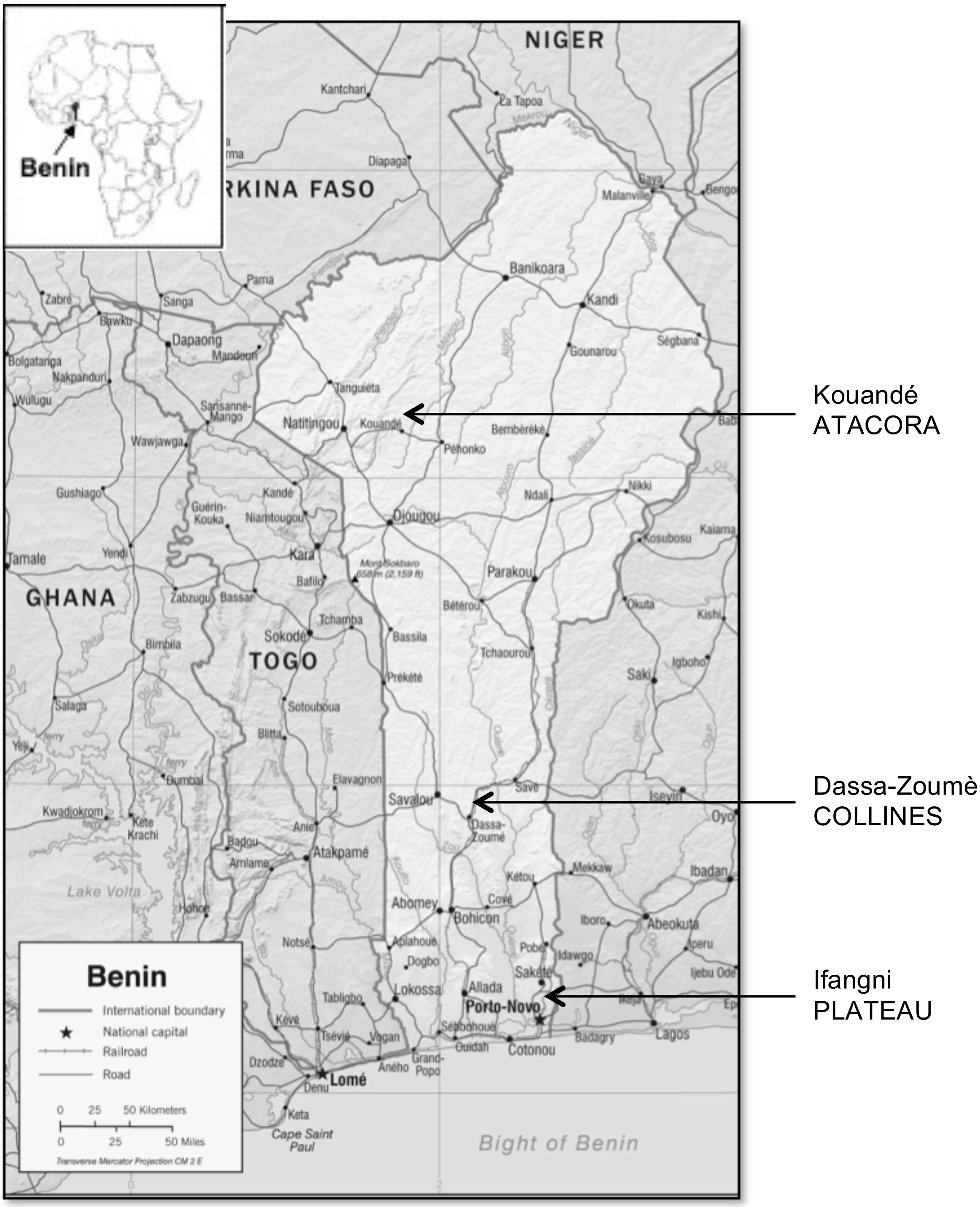


Figure 3 : Site location

The main crops are maize (*Zea mays*), cassava (*Manihot esculenta*), oil palm (*Elaeis guineensis*) and vegetable (chilli pepper, tomatoes and green leafy vegetable). The secondary crops are groundnut (*Arachis hypogaea*), cowpea (*Vigna unguiculata*) and sweat potato (*Ipomoea batatas*). The main cash crop is oil palm product. Oil palm trees are planted in all the land and are a sign of wealth. The farmers do not grow cotton because the agro-ecological conditions are not favourable.

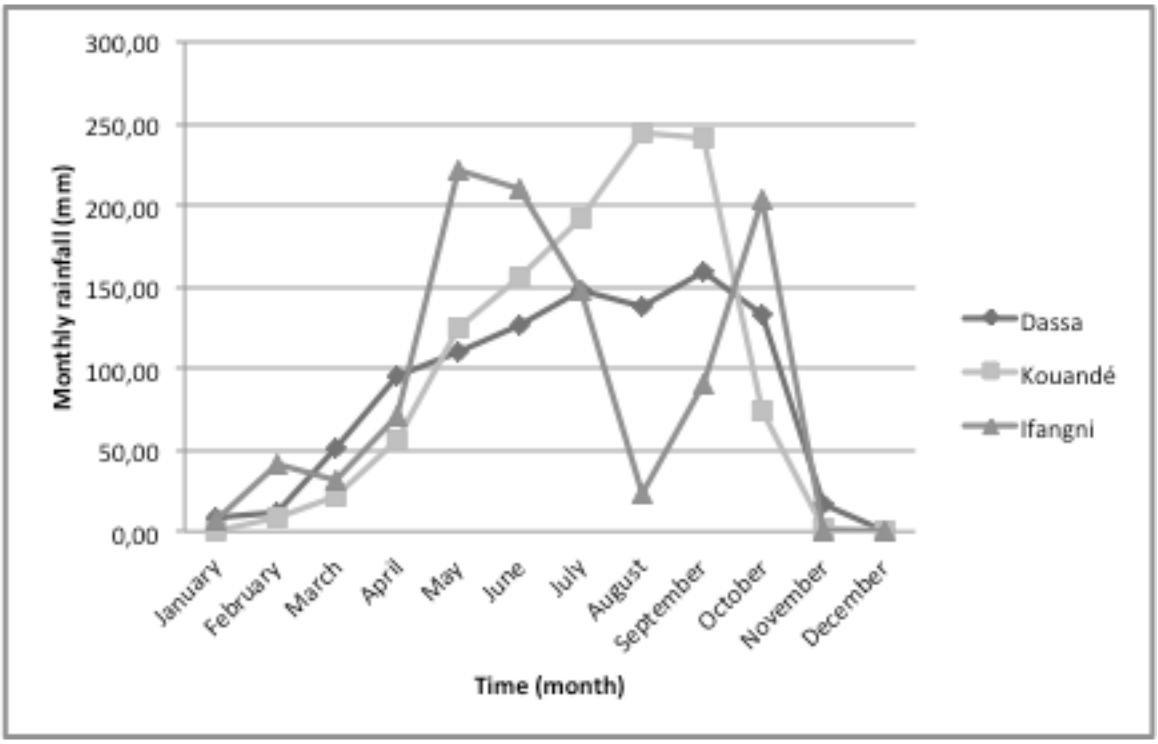


Figure 4 : Rainfall pattern in the three different agro-ecosystems (source : CeCPA Ifangni, CeCPA Dassa-Zoumè, CeCPA Kouandé)

The access to credit is very limited. Indeed agricultural activity offers little economic returns and is too risky for bankers. The access to mineral fertilizers is also very limited. As farmers do not grow cotton, they don't have access to fertilizer on credit and can only buy them cash. Also, the amount of mineral fertilizer available for farmers is very limited (only 1000 tons in 2011 for the two regions of Ouémé and Plateau, ONASA, 2012).

3.1.2. Miniffi village - Dassa-Zoumè district – Collines region

Dassa-Zoumè district is located in the central Benin and is crossed by the main road relying the south and the north of the country (Figure 3). This district, with an area of 1711km^2 numbers about 129 982 inhabitants (INSAE 2012). The population density is still low, with about 76 inhabitants per km2. According to Igué et al. (2008), the demographic pressure is not strong so that the pressure on land is not a limiting factor.

The main ethnic group of the area is the *Mahi*. They are ancient fisherman from Ouémé region (Porto-Novo) that migrated to the North, and settled down in the centre of Benin in the XVI century. Christianity is the main religion. Traditional religions and Islam are following.

The physical relief is uneven, with hills oriented North-South, and drop reaching 200 metres. Dassa-Zoumè district is located in the Guinea zone, characterized by moist woodland and savannas (Wezel et al. 2000).

The climate is a climate of transition between the subequatorial bimodal climate and the Sudan-Guinean climate (Figure 4). The annual rainfall average is comprised between 800mm and 1200mm. Rains are uncertain depending on the year, the region can suffer from flood or drought.

Tropical ferruginous is the most common soil in the area. Their richness depends on the parent rock. They are often shallow, pebbly, and sensitive to compaction and to erosion. We can also find Vertisols and hydromorphic soils in depressions, which are richer but with variable water retention capacity.

Major crops in the area are maize, cotton (*Gossypium* spp) and soya (*Glycine max* (L.) Merr). They also grow groundnut, cowpea, cassava, yam (*Dioscorea* spp), and rice (*Oryza* spp). Staple crops are predominant but since few years, we can notice an increase of the area sown to cotton because of the attractive price of cotton. Cotton as cash crop plays a strategic role in the rotation. Indeed, the cultivation of cotton makes possible for farmer to refinance the following agricultural season and access inorganic fertilizers on credit. Also, we can see that the area of soya increased. In the mid-1980s, farmers started to grow soya in the region. Women developed knowledge on how to process it on cheese and milk. The presence of new actors, such as agro-industrial (feed miller) intensified soya production. About rice, it is mostly grown for family consumption because appreciate by children. More recently, international development projects tried to develop organic production of rice for export.

The access to credit is limited to the cotton production. They used to have an agricultural credit cooperative in the village but as the refunding of the loans was bad, it bankrupted few years ago.

3.1.3. Kouandé - Atacora

Kouandé, the third administrative district visited, is located on the Atacora region with difficult access by road (Figure 3). The population density is one of the lowest of the country, with only 24 inhabitants per km^2. Most of population are farmers. Three ethnic groups are present. The *Bariba* are the main ethnic group with 46,6% of the population, followed by the *Bètamaribè* (24%) and the *Peulhs* (17,9%). The *Peulhs* are herdman (process milk into cheese) and cultivate some land mostly with sorghum, maize and cotton. The *Bariba* and the *Bètamaribè* are farmers. They hold very few livestock compared with the *Peulhs* and use the cattle as draught power. The dominant religion is Islam (38,5%), followed by traditional religion (30,2%) and finally Christianity (14,8%) (PDC Kouandé, 2002).

The climate is Sudan-Guinean with only one rainy season (from mid-April to mid-October) and one dry season from November to March. Annual precipitation varies considerably between years from 1000 to 1300 mm (Figure 4)

The Atacora region belong to the Southern Sudanian zone dominated by woodland and savannas (Wezel et al. 2000). The districted is located on Atacora mountain chain what makes the soil vulnerable to erosion. The altitude varies from 400 to 650 m. Soils are predominantly tropical ferruginous with sandy subsoil (Faure 1977). Soils suffer from crusting and compaction. They have limited depth, and a limited inherent fertility (few exception).

In the district, family members mainly provide the labour force. The main crops are maize, cotton, yam, cashew (*Anacardium occidentale***)** and soya. During the last decade, the area cultivated of soya, cotton, maize, yam and rice increased considerably. The expansion of the area cultivated in cotton is recent and due to its higher profitability. Farmers have lower yield but earn more money. Cashew production is also increasing because of the development of more structured market chains and the creation of specialized farmers' organization. The interest of cashew production is: (a) the harvest occurs during the dry season, (b) it is not painful, (c) it does not ask for lots of extra-labour and (d) it brings additional incomes.

Farmers have access to credit and mineral fertilizers through the production of cotton, as in Miniffi.

3.2. Study design – Research activities and process

The study was carried out during 6 months from May to October of 2012. The study was designed to address the study's objectives. The annexe 3 presents the study's design. The research process consisted in different steps, detailed below:

Preliminary work conducted at Wageningen University in collaboration with the Netherland team aiming at justifies the study.

-Conduct a literature review of previous research on innovation, Local/Traditional Knowledge and ISFM in SSA.

-Conduct JOLISAA project documents review to obtain insight about JOLISAA project, its objectives and the results already obtained (Innovation case summary – Report about the first National Workshop)

-Redaction of the research proposal that contain the context, the study justification, the research questions and hypothesis, and the work plan and methodology. The second part was conducted in Benin, in collaboration with the Benin's team and consists in the *exploratory phase:*

-Conducted preliminary interviews with experts in ISFM in Benin (researchers, NGO representatives), to help in identifying an initial list of site (location) where the study may be conducted.

-Conduct an exploratory fieldwork survey in different region of Benin. It consisted in travelling through different locations to visit places where ISFM was implemented with the aim of selecting three sites where the in-depth case studies will be undertaken. The objectives were to explore possible study area, to have an overview of what ISFM is in Benin and also an overview of the agricultural sector. It also served to establish first contact with key informants at the village and district level. Key informants mentioned by the preliminary expert interviews facilitated the introduction into the villages. During this phase, discussions were held with key informants, as well as farmers' involved in ISFM programs. Also, some farms were visited which help to test the interview guideline and to have the first observations of the practices. By key informant, we understand individuals who have an extended knowledge about the area, the community, and their livelihood activities.

-Selection of three sites – As a result of the N-XTRA workshop that took place in February 2012, it has been recommended to confirm the findings from the Mangassa village, in three (3) agro ecological zones in Benin. The sites had been selected according to different selection criteria that are resumed in Table 1 and in close collaboration with the Benin JOLISAA team. Some criteria concern all three sites and others concern each sites. The selection of the area and villages was based on its accessibility, farmers and other innovation system actor's availability and interest to the project and the presence of ISFM strategies. Then, in order to have a more extended view of the situation, all the three case needed to be located in different agro ecological zones and ISFM needed to be implemented following different approaches (top-down approach versus participatory technology development approach).

-Redaction of a report about the exploratory phase and selection of the (3) studies locations.

The third step of the study is the *in-depth case study*, which was conducted in three different locations in Benin.

-Conducted individual case study and gathering of data using triangulation (i.e. observation, documentary evidence and semi-structured interviews with key informants).

-Redaction of individual case study reports, and review of the findings according to the analytical framework to answer the objectives.

-Conducted a workshop with the JOLISAA team and main stakeholders involved in ISFM in Benin to validate the findings and further develop policy implications.

The fourth step consisted in the redaction of this Master thesis.

Each site…	All sites…
Accessible (roads)	Different agro ecological zones (different production system)
Availability and interest of actors (farmers, extension services, NGO) for the study	ISFM implemented through different approach (top-down versus bottom-up approach)
Farmers that have ISFM practices	

Table 1 : Selection criteria for three in-depth case studies

3.3. Collecting data about the case studies: Multiple sources and triangulation

A case study research should use multiple data collection methods to satisfy the principle of triangulation and to ensure data validity (Patton 1990; Yin 2002). This study relies on different types of data: documents and reports from projects, interviews, and direct observations. The principle of triangulation focus on searching convergence between findings from different sources and aims at increasing the reliability and construct validity of a study.

Project documents obtained and reviewed were used to corroborate and/or augment the interviews of the different stakeholders. It also permits to provide general information about the projects itself.

Semi-structured interview is an important tool of collecting information that the researcher cannot directly observe (Patton, 1990). Also, according to Seidman (1998), the interview of individuals that participate in organisation or carry out the process is the primary way for a researcher to investigate an organisation, institution or process. Semi-structured interviews were used at different moments of the study. First, they had been used for preliminary interviews with Beninese's experts of ISFM**.** Five (5) preliminary interviews of experts were conducted. The purposes of those interviews were to gain background on ISFM development, its definition, to obtain a list of location where ISFM has been implemented, and to provide the basis for developing the orientation of the research. The interviews provided information about the development of ISFM in some particular location, the approach from the research and the context in which ISFM had been developed.

Secondly, semi-structured interviews were conducted during the different fieldworks (exploratory phase and in-depth case studies). The purpose of those interviews were, as mentioned by Guba & Lincoln, (1985, p.268) :

- To obtain here-and-now constructions of a phenomenon
- To reconstruct previous events and activities
- To obtain projections of the future
- To verify and corroborate data from other sources (triangulation).

Semi-structured interviews were conducted with a variety of actors who participated or observed the ISFM innovation process. Those interviews provided a basis for understanding ISFM development from the perspective of the people who were directly or indirectly involved. Interviews with early adopters provide historical and contextual data. Interviews with individuals directly involved in the ISFM innovation provided data on the process and the activities that accompanied the innovation process. Some interviews fit into both categories.

Resources limited the number of interviews conducted. To ensure that the interviewees represent a wide range of actors, purposeful sampling techniques to select interviewees were used. Different objectives guided the selection of interviewees. In each location, a key informant assisted in identifying and selecting potential candidates according to selection criteria made by researchers. Also, some interviewees suggested others potential candidates. Interviewees were selected because they have distinctive characteristics. Selection criteria for interview candidates included:

-Sex: other 15 interviewees 5 needed to be women

-Number of hectare under production (sign of wealth)

-Implication of the farmer in the ISFM development (early adopter, recent adopter and not adopter)

The goal of those interviews was to ensure a broad representation of perspectives on ISFM. The different actors by case study interviewed are contained in the Table 2.

Interview guidelines were developed to outlines questions and topics that needed to be covered during the interview. Some questions were general for all interviews but some questions were

Actors	Ifangni - Plateau	Dassa-Zoumé - Collines	Kouandé – Atacora
Producers	12 producers (of which 3 women) 2 poultry farmers and 1 rabbit farmer	15 producers (of which 5 women)	13 producers (of which 4 women) 2 breeders
Farmer's Organisation	3 representatives of women farmer's organisations 4 representatives of the UCP*	1 representative of the UCP 1 representative of the Groupement Villageois (GV)	1 representative of the UCP
Extension services	1 specialized technician in vegetal production 1 representative of the CeCPA**	1 specialized technician in vegetal production	1 specialized technician in vegetal production 1 extentionist
Financial services	2 representatives of micro-finance institutions		
NGO	1 representative of NGO (OPADEB)		1 representative of GTZ
District administration	1 representative of agricultural department of the district		

Table 2: Persons interviewed according to their category in each location (*UCP: District Producers' Unions; **CeCPA: district agricultural extension service)

specific according to the type of actor interviewed. The guideline serves as a checklist during the interview.

The farmers' interviews explored: 1. Individual attributes (i.e. household size, education, landholding size, sources of livelihood, access to information, participation in groups) 2. Type of soil fertility management used 3. "Innovation discovery" questions (i.e. how farmers learn about, initiate, and communicate soil fertility innovations 4. Social network (i.e. people with whom they communicate, exchange knowledge and information).

The other actors (NGO, Banks, extension services) interviews were designed to learn information/facts about their role in ISFM development, how they interact with farmers and other stakeholders, and also gain insight in the development of new alliances, institutional or organisational innovation.

The interviews were not recorded due to technical difficulties. The researchers' notes were typed up into an interview summary.

Direct observations consist of the researcher own perceptions and investigation. It can be an event (participation in training), behaviour or physical structures (roads, distances, infrastructures). In this study, field observation came mostly from field observation when visiting farm and doing transect walk with some farmers. Farmer accompanied researchers to the field to demonstrate what was discussed.

To conclude this part, the study used a variety of tools for gathering data in order to maximize the range of information and to improve the trustworthiness of the data and then provide elements for triangulation between data sources. Nevertheless, some problems were encountered in data collection. First, one of the limits of interview lies in the fact that some of the projects and activities investigated took place more than ten years ago. Then, they were some difficulties for the participants for recalling information. Another challenge was that the interviews were led in local language and the interpretation of question in French was delicate.

3.4. Data Analysis

In this study, the analytic strategy relies on the framework and AIS concept presented part 2. It means that the theoretical framework that had been drawn was used to guide the analysis.

By using an IS perspectives, we look at innovation in a more holistic way. It is also useful to access past and on going innovation processes. The data collected were analysed qualitatively. The findings were grouped under the following themes: coping farmers' soil fertility management strategies, the context and the triggers of innovation, the stakeholders, their role and contributions, the linkage between the stakeholders, the factors influencing innovation processes, and the limit of institutionalisation of the innovations.

Numerous tools had been used to analyse the innovation process. First, we had drawn the innovation timeline when it was possible. During the innovation processes, actors, their role and interaction change and evolve. Thus, for each event, the purpose was to know who did what and when.

4. Results

This part reviews the implementation of ISFM in three agro-ecological zones of Benin. For each case, we will present the initiatives implemented, the innovations, the stakeholders involved and finally the limits of the initiatives.

4.1. Ifangni: Success story that need scaling-up and –out

The case of ISFM in Ifangni is composed of a “bundle” of innovation. The innovation process had been divided in two phases. During the first phase, the focus was on bridging the knowledge gap about soil fertility and soil fertility management by using a participative approach to ISFM development. During the second phase, the focus changed toward better integration of farmers into market, and facilitation of the access to fertilizer and credit in order to sustain the efforts made during the first phase. The innovation process is presented Table 3.

4.1.1. Phase 1: Bridging the knowledge gap with participative approach

4.1.1.1 Context: a common concern the soil fertility decline

National context

In Benin, the INRAB developed for more than a decade technologies that aimed at reducing the decline of soil fertility. From 1989 to 1998, the LSSEE research team worked for the West African Fertilizer Management Network, in close relationship with the IFDC. Their research focused on determining the optimal chemical fertilizer doses for the main crops in Benin (maize, cassava and yam, among others). During the same period, researchers from INRAB developed soil fertility management technologies such as improved fallow (e.g. *Mucuna pruriens*) or agroforestry system (e.g. *Gliricidia sepium*). Unfortunately, the adoption of such technologies remained low[6].

At the national level, during the 1990s, structural adjustment programmes with the devaluation of the FCFA, the liberalization of the market, the abolition of subsidies, and the downsizing of government services reduced the ability of poor-farmers to invest in soil fertility, by for example buying chemical fertilizers.

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[6] *Mucuna pruriens* (green manure) were greatly adopted at first for its capacity to limit the development of a weed, *Imperata cylindrica* (couch-grass) but it has been progressively abandoned

Stakeholders	Activities	Outcomes	Timeline
-IFDC -LSSEE	Determining the optimal chemical fertilizer doses		1990s
-IFDC -LSSEE -Local Farmers	"Village Level Participatory Approach"	Identification of Soil Fertility Management as focus area	1998
-LSSEE -Farmers experimenter -Technician	Initiated SFM experiments with participative approach	Initiation of SFM innovation Sharing about SFM between farmers and researchers and farmers from other places	
-Togolese industry of phosphate rock -IFDC	New partnership with Togolese industry for phosphate rock supply	Easier access to fertilizers	
-IFDC -Farmers experimenter	Establishment of working capital to access fertilizers on credit		
		Integration of some technologies into farming system	2005
-UCP Ifangni -IFDC -ONG OPADEB -CeCPA	Restructuration of UCP Creation of 3 Competitive Agribusiness Clusters	Capacity building FO – Human Capital	2006
-UCP Ifangni -Individual farmers -IFDC -ONG OPADEB	Introduction and testing of yellow maize by farmers	Capacity building	2009
-UCP Ifangni -Individual farmers -Chicken Farms -Feed mill industries	Collective selling Construction warehouse	New partnerships – contracts between farmers and buyers Financial, social and physical capital	2010
-IFDC -UCP Ifangni -Individual farmers -CLCAM -CeCPA	Initiation "*warrantage*"	Easier access to finance and inorganic fertilizers New partnerships – establishment of trust Social Capital	2011
		Limited adoption of innovations –no scaling-up or –out, reserved for wealthier farmers	Today

Table 3 : Innovation history in Ifangni district

Local context

Farmers in Ifangni district had low responsive soil due to continuous cropping of lands without adequate soil fertility management practices. The high population density hindered the use of long duration fallows. The soil fertility declining, their yield and then total food production decreased, threatening their livelihood. Moreover, the access (price and availability) of fertilizers was limited, as they did not produce cotton[7]. Besides, the use of fertilizers was possible only when the crop guarantees some cash return and at the time the staple food price was very low. Another difficulty was to find labour force because of the migration of people to cities or other countries. All those factors hindered any investment into soil fertility measures.

Thus, NARS and international institutions started to focus on increasing farmers' knowledge and skills about soil fertility, the importance of organic matter and water retention measures. They engaged financial and human resources, into a project called ISFM, with the objective to improve the response of the soil to amendment and increase the farmers' yield. They used the PLAR approach. To attain their objectives, they tried to strengthen smallholder's capacities through the identification and adaptation of strategies according to the local circumstances using a social learning approach. Encouraging social learning favoured the access to knowledge about soil fertility management (SFM) practices and its adoption. Also, they used a multi-stakeholders approach aiming at reinforcing scientists and extension worker's innovation capacity and at reinforcing private-public partnerships.

4.1.1.2 The ISFM project of IFDC: drivers of the innovation process

IFDC initiated ISFM in Ifangni district with the ISFM project that lasted from 1998 to 2005 and aimed at increasing the land productivity while preserving natural resource and soil fertility. The project involved various stakeholders. In the frame of this project, IFDC created a partnership with the INRAB, and more particularly LSSEE. The research centre was in charge of implementing the project locally. One researcher from the LSSEE was in charge of carrying the project. They selected the Ifangni district for several reasons: (1) high land pressure forcing farmers to abandon fallow or shortening of the fallow period as a mean to restore soil fertility (more than 400 inhabitants/km2 in 2012) (2) real problem of soil fertility (3) Farmers willing to adopt ISFM and to share their experiences with other farmers (neighbour, from other villages or regions). For the purpose of the project, a farmers' organization (FO) had be formed called *Glegnon* (meaning agriculture is good, in local language). The farmers that belong to the FO were willing to be involved in the project.

The project started by reviewing the local farming system, as the starting point of the research. On this district, the production system under study was the association maize-cassava and oil palm cultivation.

[7] Cotton is the only crop with which farmers are able to receive input (fertilizers, seeds and pesticides) on credit.

4.1.1.3 Innovations: social and technical innovations

During this first phase two type of innovation occurred, one social and one technical. Social innovation means a new way of doing thing. In this case, the attitude of scientists toward farmer's knowledge and transfer of technology changed. They became more receptive to farmers issues. Also, local knowledge and practices were used as a starting point of the development project. The other innovation is technical. Farmers changed their soil fertility management strategies by stopping to burn the residues, bringing back the house waste, and using both organic and inorganic fertilizers.

1. <u>Participatory process of knowledge generation about ISFM practices</u>

The ISFM project was based on social and experimental theories and combined the traditional knowledge and knowledge held by scientists. Each technological pack was adapted to the local agro-ecological and socio-economic conditions. The project worked at the village scale, with farmers willing to participate, then, it extended to other village along the five years.

The research activity was based on experiment design in collaboration with farmers and on their own production system. The objective was for them to carry out trials and determine the right chemical fertilizer dose for the association cassava-maize and for oil palm production using also other organic sources.

-First step: Participative diagnosis about soil fertility management

The first step for the introduction of the ISFM concept among the community was to conduct a participative diagnosis. This diagnosis was carried out in 1999, in the village of Banigbè. The scientists, helped by the district extension services used the so-called "Village Level Participatory Approach" with the ISFM theme. The framework of this approach started with a meeting that brought together the producers from the village, during which some of them volunteered to participate to on-farm experimentations. Then, in sub-group, differentiated by age and gender, they obtained summary information about the village, through the mapping of the *'terroir'*, of the different types of soils and their use, but also the review of their farming practices and management, and the natural resources locally available. This step allowed scientists to have a global understanding of the local circumstances and get insight about the local knowledge hold by farmers.

-Second step: Field-school and development of the technologies

The second step was the collaborative design of the crop itinerary according to the capacity of the farmers. The technological options associated the knowledge hold by scientist and the practical local knowledge hold by farmers. The scientists gained knowledge through their connection with other scientists worldwide and their own on-station experimentation. They shared this knowledge with farmers to help them design the options. Each crop itinerary should used chemical fertilizers (NPK/Urea), associated with some organic fertilizers (household waste, animal manure, legumes), phosphate rocks and also improved seed (Maize DRT and cassava). They were also asked to follow sound agronomic practices such as avoiding to burn crop residue, and to use good fertilizer doses, application type and time.

The first year, thirty farmers (men and women) volunteered. The experimentation field took into account the local practices. Farmers were not forced to have a particular previous crop (legume or not), a particular soil preparation practice (flat-planted or ridge planting), or to associate maize with cassava. Therefor, it enhanced the willingness to farmer to experiment the technologies. The producers already used some of the technologies from the package proposed by scientist. They were used to use household waste and animal litter but those practices were not so common.

During the project, within the GLEGNON organization, several meetings between producers–experimenters and researchers were organized. The producers were encouraged to share their opinions and experiences with the technology with other farmers. From those discussions, they made modifications and adapted the technology. Also, it enhanced learning process and promoted dialogue among actors.

Besides, they received some training about integrated soil fertility management to gain additional knowledge and skills and also about the management of organic matter, the production of compost, the use of mineral fertilizers, improved fallow and about cultivation techniques.

-Step three: Diffusion of knowledge

Through the process of knowledge generation, information were collected about the technologies experimented by the farmers, and these information were spread to other farmer to wider the adoption within the community. Different mechanisms were employed to disseminate the knowledge and results. Farmers returned the knowledge acquired during the formation they participated in and their experimentation on the field through farmer exchange visits. Another mean to share the result of the experimentation was the publication of technical review about the association maize-cassava for other technicians involved in development programmes.

2. Changing practices and integration of different knowledge about soil fertility management

Farmers have their own classification of soil according to their fertility. They also developed practices to limit the decline of the soil fertility. Those practices are: the use of household waste and manure to fertilize the land, natural fallowing, association cereal and grain legume (maize and cowpea or groundnut) and rotation cereal – legume (cowpea or groundnut). On the other hand, scientists have knowledge about practices and process such as: the use of cover crop (such as *Mucuna* spp), the use of Natural Rock Phosphate, the use of inorganic fertilizers (quantity and date), the use of combination of organic and inorganic fertilizers and nutrient recycling.

With the different experimentations made by the producers during the project, and the diffusion of the knowledge acquired, farmers in the area changed some of the practices used to manage their soil. Most of them started ploughing the soil to incorporate crop residues and conserve the moisture instead of burning the residues. This is one of the major changes for farmers. Some became more conscious of the role of legume in the rotation and the importance to preserve their residue. Luckily, legume is part of the traditional diet of the people from the area, especially pea cow and groundnut. Also, they use to rotate with tubers such as cassava that relieve soil compaction. Other started to park their animal to preserve the manure and amend their soil with it. Also, most farmers used to burn the residue from the transformation of oil palm seed, but with the experimentations and the knowledge acquired, they started to bring it back to the field as organic matter. The use of mineral fertilizer was at the very minimum before the project began, as it was out of reach (availability and price) for most farmers in the area. Nevertheless, they were conscious that it comprises their yields. Indeed, before the ISFM project, another project called Sasakawa Global 2000[8], tried to implement high cost technologies for maize production (improved seed and fertilizers) through technology package and transfer of technology approach. Then, the producers already knew the importance of using fertilizer to obtain good yields, but they were not conscious of the importance of using both chemical fertilizer and organic fertilizers. It is through the process of the farmer field school that the farmers understood it.

Most important, all farmers involved acquired new skills and competencies to manage the fertility of their soil, and put them into practice. The changes were not total, but small change had effect on their yield. Most of them were not able to continue exactly the crop itinerary used during the experimentation plot. They adapted it according to the amount of material available on the farm and the labour forces at their disposal. For example, the dose of chemical fertilizer rarely reaches the recommended rate. The Table 4 shows the evolution of soil fertility management practices of farmers.

[8] Sasakawa Global 2000 is an international project launched between 1989 and 1993 in Benin and aimed at increasing the use of improved technologies by African farmers for maize production. They developed packages with improve maize seed and fertilizers and implemented on farm testing plots

Old practices	Introduced practices	Current practices - Adaptation
Natural long-term fallowing (good land availability)	Improved fallow with Acacia	Fallowing with Acacia (if good land availability)
	Green manure with (*Mucuna* spp, *Aeschynomène*)	Short term fallowing with cassava (local practice)
Slash-and-burn (easier soil work)	Conservation of crop residues	Conservation of crop residues
Use of household waste (limited amount, surrounding fields)	Conservation of household waste, animal manure and compost production	Conservation of household waste, animal manure and production of compost (if high value crop)
No rotation	Rotation maize-legume	Rotation: maize-legume (cow pea, groundnut) and maize-cassava
	Mineral fertilizer	Mineral fertilizer (if financial means and rain)

Table 4: Evolution of soil fertility management practice in Ifangni district

4.1.1.4 The access to the technologies needs other changes: facilitate the access to organic and inorganic fertilizers

The IFDC project intended to introduce the use of Phosphate Rock (PR) by farmers. The importation of fertilizers in Benin extremely controlled, and only the enterprises selected by the government and other stakeholders can import fertilizers without a high import taxes. The IFDC created a partnership with the "*Office togolais de phosphate*" and an import company (ECA). Unfortunately, the ECA closed and IFDC now directly accesses PR by contacting the National Togolese Company called "*Société Nouvelle des Phosphates de Togo*" (SNPT).

As mentioned previously, the access to other fertilizers (Urea and NPK) was very limited because of their price and availability. Therefor, in order to facilitate the access to fertilizers to the poorest farmers, IFDC created a working capital for farmers willing to use fertilizer and experiment the crop itinerary. Also, as fertilizers were not free but on credit, it put farmers in real situation, where their output products needed to be high enough to recover the investment made in fertilizers. Unfortunately, after the end of the project, this working capital failed due to human management error.

Besides, farmers in the area did not possess a lot of livestock. Then, as the project wanted for farmers to use both inorganic and organic sources of fertilizer, they offer some livestock (pork, goat) to some of them, so they can produce animal manure. Unfortunately, during the last years, some livestock have been hit by disease then preventing farmers to use organic manure.

4.1.1.5 Roles and interactions between the different stakeholders

Before the project began, some producers were only in contact to some extend with the public district extension services. When the project started, new actors entered into the local food system: the scientist, its technician, and the IFDC. We cannot say that they were not presented before, but their action toward the community increased. The scientist was from the locality, which facilitated the contact with local people. The technician was also a local person that already had some knowledge about the local context. The fact that previous relationships were already established before the beginning of the project may have influenced positively their acceptation into the community.

The different role played by the stakeholder are reviewed Table 5. The IFDC project was based on multi-stakeholder partnerships. The first partnership created was between the IFDC, the coordinator of the project and the LSSEE the project implementer. Researcher from the LSSEE involved farmers of the *Glegnon* organization as partners in the process of soil fertility management technology testing. Then, another partnership was created between the IFDC and a Togolese phosphate rock industry to enhance the access to phosphate rocks.

Actors	Role
IFA-USAID	Project funding - donors
IFDC	Project coordinator – Financial support to innovation (credit, animals, formation, farmer-field-school)
INRAB-LSSEE	Partner institution responsible for implementation of activities on the field – inputs supplier (fertilizers and seeds) through SONAPRA connections – training on SFM practices – Facilitation of farmers-field-school – technical support and facilitator of innovation Source of scientific knowledge about SFM practices using both organic and chemical fertilizers
Technician	Assisted farmers in experimental plot – provided farmers' technical support Source of scientific knowledge about SFM practices
SONAPRA	National Fertilizer suppliers (NPK, Urea)
GLEGNON farmer's organization	Project Beneficiary: keep written data – inform other farmers – encourage participation of other farmers to demonstration and events – Impulsion of the innovation Source of agro-ecological and socio-economic knowledge, undertaking research and adaptive testing, technology adoption, identifying research priorities and evaluating research performance
Togolese phosphate rock industry	Producer and input retailer of natural phosphate rock from Togo – Establishment partnership with IFDC to facilitate to access to NPR to farmers

Table 5: Stakeholders' role (Ifangni: 1st phase)

4.1.1.6 Conclusion

During this first phase, farmers became more conscious of the need to better use available renewable resources. The maize yield increased significantly from 800 $kg.ha^{-1}$ at the beginning of the program to $2,2t.ha^{-1}$ in sole crop and $1,8t.ha^{-1}$ in association with cassava at the end. They also improved their social capital through the use of group-based approach and the creation of knowledge sharing place. New links between farmers, scientist and the technician were created. They worked together as partners, and intended to solve jointly soil fertility decline issue. Scientist used a different approach and paid attention to local farming system and farmers' knowledge. Farmers' financial capital increased because they obtained better yield by using ISFM practices but not as promises because the price of food crop went down.

4.1.2. Phase 2: Facilitating the access to input, output and financial market

4.1.2.1 Changing context: new challenges and opportunities – focus on output and input market – the 1000s+ project

At the end of the first phase presented before, the farmers from the area had more responsive soils using during several years organic and inorganic fertilizers and stopping crop residues burning. However, they had to face high prices of the inputs, low prices of farm products due to poor market and transport linkage, and also low availability of fertilizers (in quality, quantity and time) as well as the poor access to credit system adapted to agriculture.

Therefor, in 2006, IFDC implemented the 1000+s project. The focus changed toward making the best-fit solution more profitable to farmer, meaning enhancing the economic viability of ISFM, which is the basis of the scaling-up process, by creating an enabling environment (market and institutional changes). To do so, they oriented their efforts toward better market integration in order for farmers to obtain a better price for farm produce. Also, they focused on reinforcing FOs capacity and the links between food chain stakeholders. Other changes were needed, such as facilitating the access to fertilizers and credits through new credit system called "Inventory Credit System".

During this project, new actors became part of the innovation system, other changed their role and other disappeared. Different innovations were developed:

-Re-organization of the district farmers' organization by crop, and creation of Competitive Agribusiness Cluster for maize, cassava and oil palm

-Production of yellow maize instead of white maize for feed mill industries and chicken farms

-New way of selling product (collective selling)

-Implementation of a new system to obtain credit and fertilizers (“warrantage” also called “Inventory Credit System”)

4.1.2.2 Innovations: organizational, technical and institutional innovations

Several types of innovation were initiated during this second phase.

(a) Farmers’ organisation and capacity building as organizational innovation

The first type of innovation in this phase is an organizational one. The previous project was working at the village scale, but in order to scaling-up the success, the scale of action needed to be raised up. The farmer organization at the district level in Benin is called *Union Communale des Producteurs* (UCP). It groups the producers at the ground and the village producers’ organizations. The IFDC and OBEPAD NGO helped by the CeCPA (the extension service) facilitated the re-organization of the FO in 2006. The UCP had been organized in 8 “*filières”* (e.g. maize, cassava, oil palm). At the village level, producers (farmers, breeder and processors…) come together and formed village cooperatives (or organizations). Today, UCP numbers 236 villages organizations, 109 women organizations and a total number of 12 692 members with more than the half being women (7883).

The aim of this re-organization was to have a better visibility of the producers according to their main crop and to facilitate the access to training, information and knowledge. For example, when a project propose a formation for farmers that produce vegetable, it is easier for the UCP to contact directly farmers involved in vegetable production.

(b) Responding to a market opportunity to access a more profitable output market: production of yellow maize as technical innovation

As previously mentioned, the yield and total production of maize in the area increased, which negatively impacted the price of the white maize on the local market. The consequence was that the price of the white maize was to low for farmers to continue using ISFM practices. Facing this situation, the IFDC project, and more particularly the NGO identified yellow maize as a possible cash crop, with a better market price and a local demand from chicken farm, feed miller and Nigeria. The production of yellow maize presents several advantages that favoured its adoption, as mentioned by farmers and other stakeholders. First, growing yellow maize is not so different than growing white maize. Secondly, the yield of yellow maize is higher than white maize (as the seed are improved). The yield of white maize is between 1,8 and 2,2 $t.ha^{-1}$ while yellow maize yield can reach 3,8$t.ha^{-1}$ (demonstration plot). Meetings were organized, bringing together people from demand and offer side in order to evaluate the feasibility of the project.

To gain some insight about the production and storage of yellow maize and to support the diffusion of yellow maize production, a group of farmers accompanied by other stakeholders visited some farms in Togo where farmers are used to grow yellow maize. Besides, in 2011, five farmers from the district received training about how to produce yellow maize seed to respond to the lack of national seed farm and favour the diffusion of the new crop by providing seeds to local farmers.

The production of yellow maize had two objectives as mentioned by farmers. The first objective was to produce a crop with a higher economic value, to be able to continue using ISFM practices. White maize is sold between 125 and 175 FCFA per kilograms while yellow maize is sold at 195 FCFA per kilogram. The second objective was to reduce the amount of white maize on the local market. Indeed, as some farmers replaced the production of white maize by the production of yellow maize and as the sectors asking for the two are different, the offer of white maize on the market decrease limiting the dropping of the price of white maize (Less offer – Better price).

(c) Collective selling to facilitate the link between offer and demand for yellow maize

Another innovation is the way farmers sell their harvest. It is recognized that individual farmers do not produce enough to attract commercial buyer and sustain their demand. Then, with the production of yellow maize, they started collective selling in 2010, and sold about 10 tons. This was done to facilitate the link between the offer and the demand for yellow maize. By coming together and organizing themselves in groups, farmers have more leverage on the selling price, and they can ensure to the demand of certain amount of production. Also, the organization of farmers facilitated the sharing of information related to market. Beside, bulking their produce, in 2011, 4 formal contracts had been signed for 50 tons of yellow maize for a local chicken farm and feed miller and 1,7 tons of yellow maize seed had been sold to another UCP and a local industry. In 2012, they signed different contracts with local buyers for 550 tons of yellow maize and planned contracts with local farm for 60 tons and 5 tons of yellow maize seed for other UCP. By signing contracts with buyers, farmers became less susceptible to price volatility. Also, by respecting the term of the contract, it helped building trust between the stakeholders and ensured of better long-term market for their outputs.

(d) Warrantage or Inventory Credit System to facilitate the access to adapted credit and fertilizers

The other difficulty mentioned by farmers was the access to credit and fertilizers. In the past, the only way for farmers to access credit was to have sufficient material guarantee (usually in number of hectare). Since 2010, farmers have access to credit and fertilizer through a system called “Inventory Credit System”, also called “*warrantage*” in French. This new access to credit was possible only with the support of IFDC through another programme called “Input Non-Cotton”, that started in 2009, in Benin. Partnerships had been developed between input dealers (CeCPA), the UCP (demand side) and an institution of micro-finance (CLCAM) so that farmers have another access to fertilizers and to credit.

The principle is that farmers use their production (here yellow maize) as collateral for MFI to access credit at the harvest time and at the beginning of the season also. The production harvested is store in a local storage warehouse. The storage facility is own by the UCP, and had been constructed with the financial support of the IFDC project. The extension agent from the CeCPA verifies the amount of product and its quality. They inform the MFI with a warehouse receipt of the amount of crop stored that can be use as collateral. Then, the MFI evaluate the possible credit amount that farmers can access. The credit allocated to farmers is lower that the evaluate price of the harvest in order to reduce default risks. Farmers use this credit to face the "hunger gap" and help to prevent farmers to sell their harvest at a low price with little margin. They need to refund the credit with another income, such as food processing or off-farm employment. Then, before the beginning of the agricultural campaign for yellow maize, a meeting is organized where CLCAM, CeCPA and farmers engaged in the 'warrantage' join together to establish a campaign calendar. They review the area sown, the needs in fertilizers and seeds and product to store the maize, the harvest date and the credits need. Then, farmers received fertilizers on credit, by the CeCPA at the right time, and in the right amount and type. The money for the fertilizer is directly transferred to the input dealer (here the CeCPA) and the guarantee is the harvest that is stored. Today, farmers need 3 bags of 50kg of maize, to obtain the input for one hectare (to have one bag of urea (50kg) and three bags of NPK (150kg) and seed), knowing that they can obtain between 15 and 25 maize bags per hectare.

To learn more about this credit system, some farmers and other stakeholders (CeCPA, NGO, scientists, CLCAM) travelled to Niger, to meet with farmer's organization that already does it.

The results of this new system is that it improved the access to fertilizers at the right time and in the right amount, and also facilitate the credit at the 'hunger gap' to avoid farmers to sell their harvest cheaply. The first year, in 2011, with 20,4t of maize, they obtained a credit of 2 940 300 FCFA from the CLCAM. In 2012, it will be the third time that the "*warrantage*" system had been implemented in the area. This year only 17 farmers will profit from it despite of the training and information people received. Also, as mentioned by the CLCAM agent, farmers can put more maize bag as collateral to obtain credit to finance labour force or the renting of a tractor for example, and use the "*warrantage*" as a credit to finance all agricultural activities.

4.1.2.3 Roles and interactions between the different actors

During this second phase, new actors "emerged", some changed their role and others "disappeared". The research through the LSSEE was not anymore in charge of the project but it did some participative training and experimentations about ISFM with farmers. The technician in charge of supporting farmers experiment did not have any role to play. Finally, the farmer organization, '*Glegnon*' was replaced by UCP (District Union of producers).

Besides, the role of the IFDC changed. They still play the role of intermediary between farmers and international donors but with the new system input credit, they also act as a guarantor for the CLCAM. They also helped for the construction of a storage area.

The new stakeholders are:

-**OPADEB NGO** that is the intermediary structure between the IFDC and the FO (UCP Ifangni). The NGO is in charge of implementing international and national initiatives through market studies, of facilitating linkages between farmers (FO) and other stakeholders (rural banks, commodity output and input suppliers), of facilitating the development of micro-enterprises and FOs. They also advocate for policy changes. The NGO proposed training about cooperative principles, associative dynamics, accounting and financial management, collective selling and 'warrantage', and also quality and traceability to UCP members.

-The **CeCPA** is the public agricultural extension services in Benin (former CARDER). It is mandated to provide technical, organizational and managerial assistance to farmers and establish agricultural statistics to government. Its role is very important in the farming system, as it is also the unique subsidized input supplier (fertilizers, pesticides and seeds). Today, they also participate in the '*warrantage*' system and provide yellow maize seeds and fertilizers and inspect the yellow maize storage to insure the quality to the CLCAM.

-The **municipality** created since 2011 an 'agricultural focal point', to answer the requests of producers and facilitate the work of the mayor. The person in charge of the agricultural questions works with producers from the UCP and the CeCPA. He consults those two partners before the town council and addresses their concerns. He is the interlocutor between producers and the communal council. The municipality elaborated a Communal Development Plan in which a budget is allocated to issues regarding agriculture. For example, in 2012, the budget is 200 000FCFA (300euro). In 2010, in order to promote the production of yellow maize, the municipality choose one farmer per village at whom it offered yellow maize seed for a quarter of hectare. In 2011, as the availability in the district of inorganic fertilizer was very low, the municipality helped farmers to obtain 50 tons from another district.

-The producers from Ifangni district formed in 1994 a USPP (*Union Sous-préfectorale des Producteurs*), recognized as an organization with collaborative vocation. In 2002, with the decentralized arrangements, the USPP became the **UCP**. It has been created with the aim to defend the interest of the producers, and to improve their work condition and livelihood. To this end, the on-going activities carried by the UCP are the structuring, the access to output markets and micro-finance, the counselling support service, and the marketing among others. They propose training according to farmers' request. Besides, they also participate in the collective selling of yellow maize. They hold knowledge about local agro-ecological and socio-economic context and help in identifying research and policies priorities to a certain extend.

-The **CLCAM** is a structure that allocates loans to farmers. It plays an important role today, because they are part of the "*warrantage*" system. It proposes loans to farmers during the 'hunger gap' and an input credit at the beginning of the agricultural campaign. The interest rate is 1,25% instead of 2% per month, thank to the IFDC guarantee fund.

-**Industrial feed miller and chicken producers** are new stakeholders involved in the innovation system. Since 2010, feed millers buy yellow maize from producers of the UCP. Some contracts had been signed.

4.1.2.4 Conclusion

The increase of food production is not an end in itself to fight rural poverty. Other concerns need to be taken into consideration. The access to input, output and financial market are indispensable to favour the adoption of expensive in time and money practices to recover or limited soil fertility depletion. IFDC with its project, intend to answer those concerns by developing organizational and institutional innovation. The UCP gained the thrust of rural bank for the "warrantage" and local authorities when winning four agricultural prices. Also, the socio-economic situation of farmer had been enhanced during this second phase with an increase of land productivity and the access to more remunerative market. Today, the new partnerships are still sustained by the presence of the IFDC. In 2013, the project that facilitates the "*warrantage*" will end, and UCP farmers need to organize and coordinate their actions so that the initiative continues.

Finally, the number of innovator is still very limited and scaling-up of those prosing innovation need greater attention. It should be noted that the government and policy-makers were not involved truly during the entire innovation process, which may explicate the slow scaling-up.

4.2. Miniffi case: Green manure, Improved fallows and selling seeds

The case of Miniffi had been divided in two phases. During the first phase, as in Ifangni, the focus was on the promotion of improved soil fertility management practices, and more particularly the use of improved fallow and green manure. The researchers used a participatory technology development approach. During the second phase, the purpose was to offer an opportunity for farmers to obtain additional income with the selling of the seed issued from the cultivation of improved fallow and green manure. The history of the innovation is presented in Table 6.

Stakeholders	Activities	Outcomes	Timeline
-Researchers from CRA -Extension staff (CARDER) -Local Farmers	"Village Level Participatory Approach"	Identification of soil fertility as the major issue facing farmers	1998-1999
-Researchers INRAB -Technician -Farmers experimenters	Promotion of green manure and improved fallow through participatory technology development approach Diffusion through different channels	Social capital, Human capital	2002-2004
-Researchers INRAB -Extension staff (CeCPA) -Farmers	Project from CRA-Centre and AIC Formation of volunteered farmers to the production of improved fallow and green manure seeds	Capacity building, Human capital	2006-2007
-Researchers INRAB -Extension staff -Technician -Farmers	Creation of OP specialized in production legume seed of green manure – collective selling of improve fallow and green manure seeds	Financial capital	2007

Table 6: Innovation history in Miniffi village

4.2.1. First phase: Test and tailor the use of improved fallow through participative approach

4.2.1.1 Context: declining soil fertility and lack of resources

The people from Miniffi identified the decline of soil fertility as the main issue they have to face, during the "Village Level Participatory Approach" carried out in the village in 1998. During the diagnosis, handled by the Research Development group from Bohicon[9] and the CARDER (former CeCPA), producers revealed their difficulties and ranked them in order of importance. The producers explained the decrease of soil fertility as the consequence of population increase, land shortening and the decrease use of fallow. Other reasons, mentioned by researchers are: (1) no use of organic fertilizers (no intensive breeding or use of household wastes), (2) use of traditional burning of crop residues (3) and limited access (price and availability) of chemical fertilizers especially for women.

4.2.1.2 Initiating farmers' experimentations

Following the diagnosis established in 1998, the technological solution presented and proposed by the INRAB to farmers was the use of improved fallow species as a way to intensify the food crop production while preserving natural resources. The INRAB introduced different herbaceous legumes plant used as green manure (e.g. *Mucuna utilis, Aeschynomene histrix, Stylosanthes*

[9] Research-Development groups are part of the CRA (*Centre Recherches Agricoles*), which are deconcentrated research entities of the INRAB.

guianesis) or as improved fallow (e.g. *Gliricidia sepium*). A village coordination committee was created and about 10 farmers volunteered to test the different technologies on their field between 2002 and 2005. For the experimentation, the approach used by the research was the Participatory Technology Development and each technology was part of a technological package. The legume species were not proposed as a substitute to chemical fertilizers but with the aim to reduce the doses of chemical fertilizers and increase their efficiency. The objective of the research was to increase farmers' incomes by managing sustainably their field. Scientists wanted to extend farmers knowledge about the soil fertility management, the importance of organic matter and encourage them to change their attitude and practices.

Technicians and researchers closely followed the different experimentations implemented by farmers in their field in order to draw conclusions from it.

4.2.1.3 Changing soil fertility management practices and integrating different knowledge

Farmers in Miniffi developed new practices in order to cultivate their soil during a longer period of time, because of land shortage. Among those practices, we can cite: crop rotation with legume and fertilizer back-effect and fallowing. Over the last decades, other practices have been introduced by external agents and adopted to a certain extend by farmers. Among the practices introduced, we can cite: chemical fertilizers, green manure, agroforestry and the incorporation of crop residue (see Table 7).

Fallowing as explained by producers was the most widely used practices of restoring soil fertility, at the time where sufficient land was available and when agriculture was not market-led. After few years of cultivation (from two to three), fields were left fallow for many years (until more than 30 years). Then, farmers cleared up the land, cutting and burning bushes and trees to farm the land again. Over the past few decades, both the length of the fallow period and the acreage of fallow have declined in the area. Today, most farmers rely less on fallowing that they used to decades ago. Only the farmers with the larger farmland continue fallowing. The women on the other side most of the time cultivate the same land without long-term fallowing for decades. According to farmers, fallowing is the best way for replenishing soil fertility. Some lands are under fallowing since more than two decades. In those cases, the reason for fallowing is not for replenishing soil fertility, but rather because those farmers lack the means to put those fields under cultivation.

Farmers choose rotation according to their need (food crop or cash crop) and their financial means. Farmers are conscious of the importance to rotate crop as a mean to still obtain a good yield while cropping land during more years, and also to limit pest and sustain the income. Most of the time, farmers grow legumes (cowpea or groundnut) at the beginning of the season before

Old practices	Introduced practices	Current practices
Long-term fallowing	Green manure (*Mucuna utilis, Aeschynomene histrix, Stylosanthes guianesis)*	Natural short term fallowing (5-6 years) Cassava short term fallowing Green manure (*Mucuna utilis, Aeschynomene histrix, Stylosanthes guianesis)*
	Improved fallow and agroforestry (*Gliricidia sepium, Moringa*)	*Improved fallow and agroforestry (Glyrecidia, Moringa, Pigeon Pea)*
Slash-and-burn agriculture	Conservation of all crop residues	Conservation of crop residue (except cotton)
No rotation		Rotations: Cotton-Maize Maize-Legume Maize-Cassava
	Mineral fertilization on cotton and maize	Mineral fertilization (according to the financial capital

Table 7: Evolution of soil fertility management practice in Miniffi village

growing cotton. Legumes having a short cycle (2 months), they are seed at the beginning of the season (in April), and harvested in June. They choose to grow legume because they can obtain quickly a first harvest that they can sell to face the “hunger gap”, and also to enrich soil organic matter. Also, almost, all the time, after growing cotton, farmers grow maize or cotton again. Indeed, they are well aware that some of the fertilizers used for the cotton production can be available for maize. This way farmer reported using less fertilizers or no fertilizer on the maize and still obtain a good yield. About 20 years ago, farmers started growing soya, but as the growing season is the same that for cotton, they either grow it in sole crop, or as companion crop of maize. They did not report growing soya as a soil fertility management practices.

Chemical fertilizers were introduced about 40 years ago by extension staff for the cotton production. Farmers acknowledge their performances and know how to use them. Today, farmers that use chemical fertilizers, use it not only for cotton but also for maize. Farmers recognized not applying the recommended doses of fertilizers and justify it because it is an expensive and a risky technology, and also because the climate became more uncertain. This year for example, the rains started lately, making the spreading of chemical fertilizer useless.

The incorporation of crop residues and the non-burning of weeds had not been reported by farmers as endogenous practice. Actually, in the past they used to burn the residue to facilitate the preparation of the soil. Today, they still continue to burn cotton residues because they can injure them at the time of ploughing. This practice of incorporating crop residue is more of less recent according to the farmers. Some have learnt the practice from their parents and others just stopped few years ago while working with research and extension staffs. Nevertheless, through transect walk, we have seen farmers continuing to burn residue and justify themselves as a practice that increase the yield and facilitate soil preparation.

The promotion of green manure and agroforestry practices had been intensive during decades in the area. For green manure, by testing in close relationship with researchers, women mentioned it as being a soil fertility management practice that fits into their farming system, as they have poor soils, distant fields (3-4km) and little financial capital. The advantages reviewed by women farmers about green manure are that: (1) it decreases the dose of chemical fertilizers (2) it brings organic matter to the soil (3) it avoids transportation of organic matter, as it is produced *in-situ (4)* it enhances the structure of the soil (loosen the soil). The species grown are *Mucuna pruriens* var., l'*Aeschynomene histrix* and *Stylosanthes guianesis.* The men that grow the different species of green manure, does it mainly to have access to another source of income and only on a small area where the soil is degraded.

The use of legume shrubs and trees, such as *Gliricidia sepium* and *Moringa*, is reserved to men that are landowner. Farmers that rent the land are not allowed to plant perennials and women rarely possess any land. Also, only men that participated in the experimentations with research mentioned to have such trees and shrubs on their land from this time. They cut the branches once to twice a year and let them between the ridges for its decomposition.

Farmers in the area do not use animal manure even if they know about it. Indeed, only one of them used it for the first time this year and enjoyed the effect on its cotton field. He planned to continue but the access to animal manure is very limited in the area because of bad relationships with Peulh (the one having it). The use of animal manure is also limited because farmers do not have a lot of livestock and also others mentioned that it brings weeds.

4.2.1.4 Diffusion of knowledge

In order to diffuse the knowledge about the use of green manure, different methods had been used. First, the knowledge was shared with other farmers through annual village restitution, exchange visits, and the organization of '*Farmers' day*'. Annual village restitution consisted in bringing together all the farmers experimenter and other villagers to discuss the results of their work, and share their views and insights. During the exchange visits, farmers from other villages were invited and farmers that participated in the experimentations shared the knowledge they acquired. Researchers encouraged this type of exchange because "farmers are more willing to adopt the technology when presented by another farmer". During the "*farmers' day*", not only farmers are invited but also other local figures such as extension agents, FOs' representatives and members of the district council. They were invited to learn about the results of the researchers and farmers. Also, some broadcasting on local radio were organized to diffuse the knowledge to as many people as possible.

Secondly, demonstration plots with *Mucuna* were established in school grounds as a way to transfer the technology from children to parents.

Finally, the knowledge were diffused and transferred to other actors of the farming system through formations and didactic support publication. Local teams from the CeCPA and NGO received training about the advantages and technics of using improved fallow and green manure. Also, booklet explained the role of green manure, the effect on the yield, and the crop itinerary developed. Those booklets were illustrated in close collaboration with the producers in an iterative ways, and in local language and were distributed to NGOs and other partners as CeCPA.

4.2.2. Second phase: Selling seeds to promote the use and answer to a market opportunity

4.2.2.1 Context

After a few years of experimentations, farmers gained knowledge about the use of improved short-term fallow. Even if they obtained good results, they had to face the reality that cultivating improved fallow did not provide short-term extra-revenue (not eatable and not marketable) and their use efficacy is subject to climate and environment in general (fire, unstable rain pattern).

On the other side, researchers and AIC were convinced of the beneficial effect of using improved fallow and were focusing on continuing their promotion.

4.2.2.2 Innovation: new marketing opportunity: selling seeds

During the agricultural campaign of 2006-2007, research from INRAB accompanied by the AIC trained some farmers from different villages including Miniffi to the production of improved fallow seeds. The objectives were to favour the adoption of the technology by making it remunerative and also respond to a certain extend to national and international demand from other research centre. In the village, 22 farmers, among which 14 women participated. Then, some farmers, helped by INRAB researcher, in 2007 joined together to form a farmers' organization with the specificity to produce improve fallow seeds. The creation of the organization was a way to gather the offer and facilitated the access to the market of improved fallow seed. It also reinforced farmers' capacity. In 2007, farmers were very motivated, as they had been told that there was a good market opportunity for green manure seeds and produced about 13 tons. Indeed, the ABE[10] expressed its intention to buy the seeds from the farmers. Unfortunately, the ABE did not respect its 'informal' contract. That year, they only sold between 3 and 4 tons. The issue with the production of those seeds is that after a year, their power of germination

[10] The ABE is the Beninese national agency in charged of implementing projects linked with environmental issues.

decreases drastically, preventing their selling. Since then, they sold between 8 and 10 t each year and don't keep the surplus.

4.2.3. Stakeholders' role and interactions

The Table 8 shows the key stakeholders involved in the innovation process and their role, in Miniffi. The drivers of this process are the researchers from INRAB and the farmers' experimenters. During the innovation process, some of the stakeholders changed their role.

At the time of the experimentation of improved fallows, the relationships between researchers, the technician from the experimentation site and farmer experimenters were quite strong. Unfortunately, today, it is less true. Indeed, some farmers' still continue to test varieties and other technologies for research but the approach is more top-down than participative.

Actors	**Roles**	
	1st phase	2nd phase
INRAB researchers	Coordinators - Intermediary -Bring solutions to farmers problems -Conduct participative research about organic fertilizers -Organization of exchange visits *Hold knowledge about soil fertility biological, physical and chemical processes, the use of green manure and agroforestry practices*	Coordinators - Intermediary -Reinforce FOs capacity, helped them to create an organization, finding potential buyers for seeds *Hold information about improved seed buyers*
CeCPA Local extension service	Technical support -Technical advices using top-down approach with demonstration plots Input supplier	Idem
Local farmers	Key implementers and experimenters -Participated in annual evaluation meeting -Sharing of the findings with the community *Hold indigenous knowledge about soil fertility and SFM*	Key participants -Production of improved fallow seeds (production) *Hold knowledge about how to produce improved fallow seeds*
Government	Support -Supporting policy with programmes to promote the use of organic fertilizers	None
AIC	Support -Supporting the promotion of organic fertilizers -Participation in the training for seed production	Support -Support promotion of organic fertilizers and ISFM practices
International researcher centre NGO	None	Market -Demand for improved fallow seeds

Table 8: Stakeholders' roles (Miniffi)

Rarely, the farmers obtained the results of the testing and when they do, they rarely share them with the rest of the community. Also, farmers are not in direct contact with potential buyers of improved fallow seeds. The market is hardly visible, and they don't know how much they can grow, which will be sold. Only researchers with extended relationships with other NGO, research centre and international institutions throughout West Africa have this market information. Then, the relationships between extension staffs and farmers are also limited. Only the wealthiest farmers are in contact with extension staffs, and obtain their attention. It was clearly mentioned by extension staff themselves.

4.2.4. Conclusion

The research used a participatory approach focusing on soil fertility management practices with the use of organic material such as green manure and more particularly *Mucuna and Aeschynomene*. At the beginning, the research focused less on the market but as the adoption of a practice is closely link with its return on investment, it became necessary. Researchers were eager to find a way to keep farmers using seasonal fallow by forming farmers to the production of seed and then the help to create a farmer's organization to gather the offer, and find market. The reason why farmers continue to grow green manure is only because they know they can sell the seeds. As soon as the market will disappear, they will stop to use seasonal fallow. Event if the research used a participative approach, the technologies proposed by the research are not very viable. It was more a researcher wish rather than a real opportunity for farmers. At the same time, farmers developed their production of soya, on their own and responding to the nascent market opportunity from feed miller and Nigeria. Indeed, soya is a more easily marketable crop and also can be use with the double purpose of producing seed for consumption and vegetation for soil fertility. Moreover, women in the area know how to process soya into milk or cheese. Unfortunately, while focusing on introducing seasonal fallow, farmers had to develop by themselves the production of soya. Today, there is a real lack of knowledge about how to have a better yield, the use of chemical fertilizers for soya production.

4.3. Sékogourou case: multiple projects for cotton production

4.3.1. Context

The main cash crop in the northern part of Benin is cotton. During the last decade, the cotton production drastically decreased and became a national and international concern. At the same time, cotton buyers requested a more sustainable production of cotton using fewer pesticides and with ISFM practices. At the local scale, farmers were willing to continue growing cotton as long as it was profitable. They were not concerned with soil fertility decline as the availability of land was still good and they developed other soil fertility management practices.

4.3.2. Initiatives related with ISFM

Since 2007, lots of different ISFM initiatives had been implemented in Sékogourou (the study village). They are reviewed in the following paragraphs.

WACIP project (2008-2012)

With the aim to promote and reinvigorate the cotton production, the WACIP project has been implemented since 2007. This program financed by USAID (United State Agency for International Development) was carried out in four countries of West Africa (Chad, Burkina Faso, Mali and Benin). The IFDC accompanied by the AIC and CeRPA were in charged of implementing the project in Benin. Its objective was to increase cotton productivity to make the production more remunerative for farmers while preserving natural resources. To reach its objective, they use a top-down approach, by disseminating massively soil fertility management techniques (importance of residue incorporation and organic matter) and Integrated Pest Management through the formation of extension staff. The project had been implemented during the farming campaign 2008-2009, in Kouandé district. Extension staff installed some experimentation on farmers' fields, where they followed the cotton crop itinerary as promoted by the research. The way to diffuse the knowledge acquire from those fields was the cascade training model. Each farmer that participated in the training needed to form at least four other farmers. According to their final report, it seems that 128 farmers received the formation in Kouandé district.

CmiA (Cotton made in Africa) and CmiA-COMPACI project

The CmiA project received multi lateral funds from the GTZ, the Otto foundation and the Bill and Melinda Gates foundation. The project lasts from 2005 to 2012. In 2007, it became the CmiA-COMPACI project. The CmiA supported cotton producers so they change their practices. They had to respect some specifications to be able to access a quality label. The project followed the same aim that the WACIP project. They formed extension staffs that then formed farmers about composting, and sustainable agricultural practices. They were using top-down approach.

During the campaign 2001-2012, some farmers from Sékogourou, had been contacted by the CmiA project, to construct a compost pit. They received the basic supply to construct the pit and receive a training about how to produce compost and how to use it. The farmers interviewed that were willing to construct the pits, were then let alone. This year, no one came to help them dealing with organic material.

SNV Pro-cotton

The SNV Pro-cotton is a project supported by the SNV (Dutch cooperation) that works in close collaboration with the District Producer organization (UCP). This year (2012-2013), some farmers selected by the members of the UCP received a formation about ISFM by an extension staff from the CeCPA, specialized in crop production. They had been formed about the production of compost, animal manure, and the importance to combine agriculture with livestock breeding among others. Besides, those farmers were required to implement demonstration field, with half a hectare with *Mucuna* and to plant *Moringa* on their field. The farmers are called farmers-trainers.

PASA-AD and PUASA (Projet d'Appui Sécurité Alimentaire – Atacora Donga et Programme d'Urgence d'Appui a la Securite Alimentaire)

This project had been implemented with the bilateral cooperation of the Beninese government and the German government. It aimed at decreasing the effect of the food crisis of 2008, by contributing to the sustainable increase of food crop production to guarantee food sovereignty in the Atacora-Donga regions. In order to reach their objective, demonstration plots on farmers fields were implemented with the support of the extension worker. The crops were maize and cowpea, and they promote a technological package, with the use of the recommended dose of chemical fertilizers, the "good" farming practices (weeding..), and maize-cowpea association. According to the interview with a farmer involved in this project it seems that the extension worker did not share the results with the farmers experimenters.

PAFICOT (Projet d'Appui à la filière Coton Textiles)

Finally this year, Kouandé district received funds from the PAFICOT, that also use demonstration plot as a way to diffuse ISFM.

4.3.3. Changes in soil fertility management: mostly based on local knowledge

The three most important practices used by farmers to manage the fertility of their soil are: fallowing, crop rotation and the use of chemical fertilizers. The evolution of soil fertility management practices of farmers are reviewed Table 9.

Fallowing and crop rotation

Farmers in Sékogourou grow lots of different crops to secure their production, diversify their income sources, and also to rotate their crops. Indeed, the rotation is the main strategies used by farmers to maintain the fertility of their soil and be able to cultivate it during a longer period of time. In the past, farmers used to cultivate the land during a short period of time (2-3 years) before fallowing, but with the introduction of chemical fertilizer and the promotion of cotton production by the government, they were pushed to cultivate their land during a longer period. Today, generally, they cultivate their land during seven to eight ears before fallowing it. The fallow period can last from 4 to 5 years, until 15 years. Different types of fallow are used to restore the fertility of their soil..

Old practices	Introduced practices	Current practices
Long-term fallowing	Green manure (*Mucuna spp*) 2012 Agroforestry (*Moringa*) 2012	Natural Long - term fallowing Long-term fallowing with cashew Short term fallowing with cassava (2 years) Short-term fallowing (5-6 years) Agroforestry system (field edge) with pigeon pea
Slash-and-burn agriculture	Conservation of crop residues	Conservation of crop residues (feed Peulhs animals) and burning of cotton residues (except when use of tractor)
	Use of compost and manure	Use of compost and manure (only if cattle, and training, 2011-2012
Rotation: fallowing->Yam->Maize or Millet or Sorghum	Rotation: maize/cotton-> Legume	Monoculture Rotation maize-cotton -> Legume
	Mineral fertilizer on cotton	Mineral fertilizers

Table 9: Evolution of soil fertility management practices in Sékogourou village

These are detailed below

-Natural fallow lasts approximately between 8 and 15 years, with or without cashew that provides extra income. Farmers holding large fields use it.

-Short-term fallow lasts between four and five years, and it is the most widely used.

-Cassava fallow lasts two years, and is widely used by farmers to restore the fertility of their soil and start a new crop rotation cycle.

Along with the use of fallow, farmers rotate their crop with the purpose to extend the time of cultivation and still obtain good yield. Traditionally, the head of rotation is yam. They justify it because: (a) it permits to uncompact the land, (b) it is not disturb by the residues and (c) it needs fertile soils (demanding crop). After producing yam, they usually grow maize with or without sorghum, because it is the main food crop or cotton because it is a high value crop. Farmers stated that if they grow cotton or maize as a head of rotation, they obtain a low yield the first year. Then, they explained that after few years growing cotton or maize, they know that the soil fertility is declining. It is at that moment that they introduce a legume (such as groundnut or cowpea or soya) as a way to replenish the soil fertility. But today, as the market for legume is not well develop, and maize is still the main food crop, the area cultivate on legume is very small. Even the farmers holding a lot of land rarely cultivate more than one hectare. They also grow cassava as short-term fallow. Also, farmers are also conscious of the effect of cotton fertilizer on maize so, they usually grow maize after cotton.

<u>Chemical fertilizers</u>

All the producers interviewed use chemical fertilizers to increase their soil productivity. They apply fertilizers for cotton and maize. They use only two types of chemical fertilizer, as they are the only one they have access to through cotton production (Urea and NPK). The doses on cotton do not vary widely. They usually apply the recommendation dose. For the maize, the dose is adapted to the financial means, the previous crop, the availability of the fertilizer, and the soil fertility status, and the seeding date. Farmers explained that when the date of seeding the maize is late, they will apply a fewer amount of fertilizer, because they know they will obtain a reduce yield. Also, the dose applied decrease when the previous crop is cotton or when the soil is still fertile. Finally, particularly women, will not apply the recommended dose because they lack financial means. Also producers that use organic material such as animal manure also claimed to reduce chemical fertilizer doses.

Management of crop residues

Farmers are not very concerned with the management of crop residues. They explained that they burn cotton residue, because they make soil preparation hard and also can harm them. Crop residues from sorghum are use at home or burned. The other crops residues are most of the time eaten by Peulh livestock at the end of the harvest time.

Animal manure and compost

Only the Peulh in the area are used to manage animal manure. Farmers are not used to. The different reasons are that most of the field are far away from the homestead, where the animal manure is. Also, they do not possess enough livestock (only as drought power). Lately, some projects tried to implement the use of animal manure and even their transformation into compost. Today, some farmers have compost pit, but they do not used them quite frequently.

Green manure

Recently, external agents introduced the use of *Mucuna* as green manure. But so far, farmers did not show any sign of interest for them.

4.3.4. Stakeholders’ roles and interactions

The main stakeholders that have been involved in the implementation of ISFM are extension staff, international institution and funders, district farmers’ organizations, and individual cotton producers (Table 10).

The relationships between the different stakeholders of the food and farming system are weak. Even if the cotton production, in Benin, is extremely structured (inputs on credit, contracts with cotton processors…), the approach used by ARD and development program is still top-down. There is not any joint learning between parties. Farmers are still seen as technology receivers, and only rarely exchange with researchers and extension staffs. Extension services lacks of

Stakeholder	Role
Local cotton farmers	Key implementers -Test ISFM practices for cotton production
UCP (district farmers organization)	Intermediary -Link farmers experimenter with national and international project
CeCPA extension services	Input supplier -Sold subsidies fertilizers Support -Help farmers to install demonstration plot -Help farmers to obtain rural credit for cotton campaign
International institutions and funders	Funders -Finance projects related with the implementation of ISFM

Table 10: Stakeholders' roles (Sékogourou)

financial and human capacity. As they are poorly paid and do not get money for going on the field, their actions are limited. Also, previous policies put aside UCP, as active participant of cotton production. Today, they start again to be considered by government and international funders as active members.

4.3.5. Conclusion

Before, extension services that promoted the cotton production were focused on the unique use of chemical fertilizers. But lately, they tried to implement the combine use of chemical fertilizers with the use of organic fertilizers. Several projects promoted the use of organic fertilizers, such as green manure, the restitution of crop residues, the use of compost and animal manure. Several projects tried to implement ISFM but each of them used the demonstration plot as their only way to diffuse the technologies. All of them used a top-down approach. Then, in the area, few farmers mentioned soil fertility decline as an issue. They are used to rotate crop and to fallow land to replenish soil fertility.

Moreover, the practices such as composting are time demanding, need livestock and need knowledge. It is very complicated knowing that farmers in the area are absolutely not used to. Farmers that are willing to implement demonstration fields are mostly the wealthiest one, with extended access to information, through their social network. On the other side, women get their knowledge from their husband and rarely obtained any support from extension services, about crop production.

In this case, we can see that today, most farmers lack knowledge about organic matter, and the use of top-down approach did not make them understand more. Also, they are dealing between producing for their family, and earning money by producing cotton. Lots of farmers mentioned that they were not willing to increase their yield and investment.

5. Cross-case analysis

5.1. ISFM in Benin

5.1.1. Importance of the combining scientific and local/traditional knowledge and practices through participative action research

As mentioned by Engel (1997), top-down approaches that only transfer messages are less relevant than approaches that create space for knowledge sharing and experience, joint learning and reflection for agricultural development in Africa. The cases presented show that farmers are more willing to implement scientific practices and knowledge in their own farming system, if they thoroughly participate, engage their own knowledge and confront it to the one hold by scientists. In the Ifangni case and in the Miniffi case, for example, researchers created an environment where farmers can exchange and discuss their knowledge and experiences between them and with researchers. They developed new knowledge and adapted their strategies. At the contrary, ISFM initiatives in Kouandé used a linear approach where farmers knowledge was not include and only external knowledge was transferred to farmers assuming that demonstration plot is the best way to introduce new practices and the accompanying bunch of knowledge. The results of Kouandé initiatives show a very low adoption of the ISFM practices such as composting or the incorporation of cotton residues.

Also, Engel (ibid) revealed that the quality of interactions and links between farmers and between farmers and scientists is a factor influencing the success of an initiative. From this study, we have seen that farmers learn and gain knowledge through their link with other people. Those people can be their parents or relatives, neighbours, others farmers, but also extension staff and researchers. Having strong link and establishing trusts are indispensable to create new knowledge, and bridge the knowledge gap between farmers and scientists about soil fertility management. The relationships between farmers and scientists should be long-term one to farmers to keep innovate (De Jager 2007). In the Ifangni case, the scientist from the LSSEE started working with farmers in 1998. Today, even if he is not in charge of the IFDC project, he still has strong connections with UCP members, and continues giving advises and participative formations about soil fertility management. They established a relation of trust and mutual interest. Farmers need scientists to answer their questions and the wish of scientists is to see farmers' situation improved. As mentioned by farmers, farmers need continuous training.

Technologies and strategies need to be developed by farmers with the support of other sources of knowledge and not the other way around. If scientists and extension staffs only present through demonstration plot the only way to do things, they are wrong. No matter how much money they put on the development project, no results will come forward. So, scientist cannot come and propose their solutions without truly understand farmer's worldview. It means that scientist and others external agents (e.g. NGO) and extension staffs need to understand farmers' strategies and not using a blue print approach. Other studies from De Haen & Runge-Metzger (1990) and Maatman (2000) shown that farmers' objectives is a mixture of producing enough to cover family needs, generate some cash, limited the risks (risk aversion) and the long-term security of livelihood. Depending on the conditions the dominant objective(s) varies. It is important then for ISFM initiatives to take into account those variations in farming global strategies. More concretely, for ISFM, it means that smallholders' farmers won't adopt practices that do not have double purposes; such as double-purpose legume and livestock or that are too expensive (fertilizers). Practices that need time and money and that do not bring (extra) eatable or marketable products are not widely adopted by farmers. The example of *Mucuna* shows that farmers did not use it increases the fertility of their soil, but because they did not have other way to deal with *Imperata cylindrica* or because they know they can sell the seed.

Scientists need to consider local knowledge and practices for the ISFM initiatives to be effective. In the Miniffi case, researchers focused on green manure practices, which imply no direct economic return because the seed are difficult to sell, and additional work. Farmers (men and women) from the area started to grow soya and developed knowledge associated with its production and processing in milk, cheese… While farmers were developing a technology that does not fit with farmers' strategy (does not bring extra food or extra money), they might have developed a soya multiple purpose legume, as in Nigeria and other African countries.

5.1.2. Importance of linking ISFM and market opportunities

ISFM technologies are knowledge intensive but also expensive in time and money. As shown by the Ifangni case, it became difficult for farmers to continue using the practices they developed because of the lack of attractive and viable market. As mentioned by Place et al. (2003) market opportunity act as a trigger that stimulate the adoption of ISFM. Also, in their study, Freeman & Coe (2002) correlated positively the amount of organic and inorganic fertilizer applied with the selling price of the product. The initiative of growing a new type of maize to answer to an industrial and local demand for yellow maize, by linking farmers with market and input support seemed to enhance farmer's investment in ISFM technologies. Mpepereki (2001) showed the same results in their case study of double purpose soybean initiatives in Zimbabwe through the reinforcement of the linkages between the technologies, the input support and the market. Also, in the Miniffi case, researchers tried to give a double purpose for green manure by making the seed marketable. Unfortunately the links with the market are weak and farmers don't know how much they can produce, making the use of green manure limited. Then, it seems that the link between farmers and market is important.

5.1.3. Institutional changes

"Warrantage" successful to facilitate the access to inputs, technologies and credit

As shown by the study from Adamu & Chianu (2011) and the Ifangni case, "warrantage" is an effective system that can address practical constraints by increasing farmers access to adapted farming credit, modern farm inputs (mineral fertilizers, improved seeds) and also better output market prices. With the implementation of the Inventory Credit Scheme, the links and trusts between UCP, the FMI and the input supplier had been strengthened.

Strong farmers organizations: Bargaining power – collective selling

From the experiences described in Ifangni, it is shown that Farmers' Organization that are well organized and well functioning had a better links with others stakeholders of the farming and food system. The MFI with the « warrantage » system developed trust relationship with farmers from the UCP. De Jager (2007) also demonstrated the role of strong FO for agricultural development in Africa.

5.2. Analysis of the innovation process

To organize the analysis of the results obtained from this study, this part will be separated by themes which are: the innovations types and nature, the innovation process (triggers, origin, associated activities), status of innovation, stakeholders and contributions, the enable environment, and the beneficiaries.

5.2.1. Description of the innovation as outcomes of the process: Types of innovations and Nature of innovation

In the three cases, the innovations were mainly technical with new soil fertility management practices but were also accompanied with organizational, institutional and social innovations. It is known as "bundle" of innovation. The Ifangni and Miniffi case well illustrate it. First, the innovation was technical and then has been combined with new organizational, structural and institutional arrangements.

The innovations were linked with the production but also with the service delivery and the marketing. In the Ifangni case, the innovation was related with production (soil fertility management and yellow maize) but also with the development of new credit scheme to access inputs ("warrantage") and also with the marketing of product (feed miller and chicken growers).

5.2.2. Dynamics of the innovation process

5.2.2.1 Main triggers

The triggers of the innovation changed along the innovation process. The first trigger in the Ifangni and Miniffi cases was an environmental stress: the decline of soil fertility with its consequences on the yield and general farmers' livelihood. Then, later the trigger became a market opportunity for the Ifangni case with yellow maize and for the Miniffi case with demand for improved fallow seeds. In the case of Kouandé the trigger was both environmental with the degradation of natural resource with the over-exploitation of land with cotton, but also a market opportunity for more sustainable cotton at the same time.

5.2.2.2 Origin of innovation processes

In each cases described, the innovation was drive and initiated by external action from programme or project. It was a planned process. International and national concerns about soil fertility supported the development of ISFM, by funding actions related to the issue. Their actions aimed at increasing the soil fertility through the diffusion of sounded soil fertility management practices in order to increase farmer's yield and incomes. In the Ifangni site, the IFDC used the ISFM approach and the CASE approach to address soil fertility concern, targeting mainly the wealthier farmers. In the Miniffi case, the INRAB scientists through the introduction of improved seasonal fallow especially targeted women. It was a research-led and development-led initiative. Researchers first started with on-station experimentations and then the technology was adapted through joint learning process. Finally, GTZ and other international cooperation funds targeted male cotton producers and tried to implement compost pits. It was a development initiative.

5.2.2.3 Associated activities

The development of innovation was associated with a wide range of activities, mainly training and capacity building of stakeholders but also the initiation of exchange visits, on-farm experiment. In the case of Kouandé, first extension services receive training about soil fertility management and then transfer the knowledge to farmers. In the Ifangni case, farmer joined together to discuss and share knowledge and experience during the on-farm-experiment. Also, exchange visits were organized in other villages and even other countries.

5.2.3. Innovation process dynamics and current status

All the cases are not at the same stage of development. In the Ifangni case, the focus change toward better market integration of farmers, and also changed scale, from village to district. In the case of Miniffi, the innovation is not scaling-up as the links with the market are very weakened. In the Kouandé case, the innovation is in it early stage of development. The first experimentation of manure pits started only few years ago, and the results are not very conclusive.

5.2.4. Stakeholders and their contributions

In the three different cases, a wide range of stakeholders was involved: individual smallholder farmers, Farmers' Organizations, extension services, formal research, NGOs, and private sectors.

The private sectors, including the input and output side were not easily visible. In Benin, private input suppliers are not present because fertilizers and improved seeds are subsidies by the government and supplied by public extension services. In the output side, the involvement of the private sector was linked with marketing innovations. In the case of Ifangni, new institutional arrangements had been created with the private sector involvement, such as feed miller.

5.2.4.1 Knowledge sources

The sources of knowledge are mixed in all the cases. The local knowledge about local context and farming system were mixed with external knowledge from research, NGOs and extension services that have knowledge about crop production, financial management and enterprise development skills.

5.2.4.2 Roles of stakeholders

Each stakeholders involved in the innovation system contributed to some extend to the innovation development. The different role of stakeholders in the innovation can be: leader or co-leader, active participant, minor participant or not a participant. In all three cases, individual smallholders farmers played the role of leader or co-leader. They were actively involved in the development of the innovations, by experimenting. They can also be classified has active participant. In the case of Ifangni, FOs became a co-leader during the second phase of the innovation process and active participant. FOs acquired a status and is the representative of farmers. They played different roles such as: sharing of knowledge through training, access to support from external donors, participate in policy-making, represent local knowledge and experience and social capital. NGOs in the case of Kouandé and Ifangni are co-leader of the process. They mostly played the role of transmission belt between external funds and local needs and supported in term of knowledge and finance the innovation. The private sector was not an active participant in the Miniffi or Kouandé case, but only in the Ifangni case. The extension service was a co-leader only in the Kouandé. They were only partly involved in the other two cases. The municipality were only a minor participant in the Ifangni case. The research played an active role and co-leads the innovation process during the first phase of the Ifangni case, and during the Miniffi case.

5.2.4.3 Interactions between stakeholders

The relations between the stakeholders involved in the innovation process are of different kinds. During the innovation process new interactions between the stakeholders were created. In the

Miniffi and Ifangni case, the relations between the researcher and farmers changed when conducting joint learning about soil fertility management by including local knowledge holds by farmers and scientific one.

Also partnerships were created in the Ifangni case with extension service as input supplier and local credit enterprise (CLCAM) for the development of “warrantage” credit scheme system. Besides, they also created informal and formal partnerships with chicken grower and feed miller for the selling of yellow maize through contracts. In this case, IFDC played a central role in facilitating and coordinating relationships that are required for the innovation to be successful and long term.

In the two other cases the interactions between farmers and other stakeholders were still very weakened.

5.2.5. Enable environment

5.2.5.1 Policy

International concerns about soil fertility decline in Africa and its link with food security is in favour of the ISFM development in Benin, with the great allocation over the last decade of international funds.

National agricultural policy to a low extend encourages ISFM by facilitating the access to fertilizers by subsidizing them. But with the high corruption rate, farmers rarely access them at the ‘normal’ price. In the Kouandé case, government making cotton production as a national priority created a favourable environment for the development of ISFM for cotton production. But, it also means that others crop production are more or less put apart.

5.2.5.2 Institutions

The attitude of stakeholder plays a major role in the success of innovation. Scientists involved in ISFM initiatives changed their attitude toward farmers’ knowledge and started considering it and including it. This change of attitude from scientific side was not seen on the extension service side. They continue to use the conventional knowledge pipeline concept, and lack financial means to conduct participative research.

Also, in the Ifangni case, banker change their attitudes and stopped seeing farmers to a certain extend as bad payers with the good result of the “warrantage” system.

5.2.6. Benefits

The parties that beneficiated from the innovation can be classified in: initial innovators and stakeholders and society at larger scale (including environment). In the different cases, the main beneficiaries were the innovators, but to a certain extend the environment also beneficiated of it through the limitation of soil fertility degradation, by using ISFM practices.

6. Lessons learnt and the way forward

In this section, we will present the recommendations for scaling-up the successful initiative presented in the cases.

6.1. ISFM recommendations

6.1.1. Developing interactive learning environment and learning capacity

ISFM is knowledge intensive. Then, it is important to understand how knowledge is create, arrange and diffuse among farmers. We have seen that farmers learn from other farmers, from scientist and extension staffs and also by experimenting. Some farmers are more knowledgeable that others and are presented by others farmers as the person which transfer the knowledge. It is indispensable to use those farmers to diffuse innovation, as they already act informally as knowledge brokers. In Ifangni, for example, the secretary of the UCP acts as it. He is a natural innovative farmer, trying things out and informing other of its findings. Also, he accesses external knowledge with training, and participating to experimentations. Besides, researchers and extension staff are other stakeholders mentioned by farmers as knowledge brokers. Then, the capacity building of those agents is important. While gathering information about the case, extension staff seems to have limited means (time and financial), but they also lack knowledge and solutions to farmers' problems. They are still using a linear approach of technology diffusion using only demonstration plots. They do not have a participatory approach attitude. Also, as mentioned by de Jager (2007), as they act as facilitator, they need to have the skills to integrate local knowledge and external science based knowledge, and use a client-service orientation and be able to carry out truly participatory projects. Then, it seems important to train those extension agents and increase their financial means.

Farmers continuously experiment to find better strategies. But they do not use any formal way to document their findings and no formal meetings are organized so that the experiences can be transformed into knowledge. The capacity of farmers to experiment in a more formal way needs to be enhanced, as it is through farmers-field-school (FFS).

Also, space must be create where farmers, scientist and extension staff can share their knowledge and experiences, such as platforms in the long run and not only during FFS or PLAR.

6.1.2. Facilitating the access to input, output and financial market

Farmers engage in ISFM need to be more secure about their production. Without a good produce market opportunity, they rarely invest in the soil fertility by purchasing improved seed and chemical fertilizers. As the cases shown, ISFM means that farmers need to engage more money in their farming system, meaning taking more risks. When farmers have a better access to remunerative market, they are more willing to invest in soil fertility.

Unfortunately, it is not enough to sell farming product at a better price. In Benin, the access to inorganic fertilizer is very limited. The amount available through the government extension services is very low, and also farmers need to pay cash. Then, without appropriate system of input delivery, the use of fertilizer is dedicated to the wealthier farmers, with strong connection with the extension services staff. The "warrantage", then, seems to be a good new institutional innovation to enhance farmers' access to inputs and credit, as shown in the Ifangni case. The "warrantage" system had been proven effective in enhancing farmers' access to credit and assuring MFIs in the Sahel zone (Pender et al. 2008). This type of credit scheme should be favoured in other places in Benin, where the access to input is limited. In the northern part, where farmers grow cotton, the fact that only cotton fertilizer is in credit, create distortion. Farmers won't use the right amount neither for cotton nor for maize production.

Kelly et al (2003) argued that in order to increase farmers access and use of fertilizers African government should focused on the difficulties linked with the provision of public goods (e.g. roads, irrigation, market information systems) and enhance institutional setting (e.g. systems of grades, contract law and enforcement) to encourage the creation of a more effective private input supply network.

6.1.3. Policies that support ISFM

The case studies shown that farmers are more willing to use ISFM practices that have a double purpose or when the practice is a by-product such as: breeding and the production of animal manure, or multiple purpose legume. Then, the government could support the legume and agro-pastoralism (pork, rabbit, poultry production) production.

Another important point to mentioned is the funding of agricultural research and development by the national government and it other policies related to food. Beninese government, in accepting food aid and the importation of food at very low price discourages producers and threaten their livelihood. For example, in the district of Ifangni, the government creates unfair competition by selling import and subsidies food at a lower price than the one produce by local farmers. This creates market disruption and put enterprising farmers into difficult position.

Also, policies aiming at increasing agricultural production (such as Beninese policy) should not only focus on agricultural research and development but also other producing factors should be taken into account, among other, we can mentioned: the existence of infrastructure such as roads to facilitate the transport of raw products, or favouring the development of market. Today, if farmers produce more they are not in position to sell it at an interesting price.

Another important institutional issue is the access to fertilizer. As mentioned previously, the Beninese government by controlling the fertilizer importation hinders any private suppliers to engage money in Benin and become part of the food and farming system. Also, the high cost of fertilizers and relative low price of food crop prevent the development of private fertilizer market in Benin.

Finally, the government could support the "warrantage" initiative that took place in different district of Benin, by favouring the construction of warehouse, and support rural banks in this initiative.

6.2. Innovation recommendations: "Partnership and learning are at the heart of the innovation process".

6.2.1. Capacity building of stakeholders

Asenso-Okyere & K. Davis (2009) did an extensive research about the policies that could encourage the promotion of knowledge and innovation in African agricultural development. They especially express their concerns about the limited capacity of stakeholders of the farming and food systems. Participatory agricultural research had been proven to be effective in helping farmers to innovate and increasing their productivity. But, doing participatory research requires special skills in term of learning process, and learning facilitation from extension services, NGO and researchers.

It is still important for research to produce research product, but they should also supported the entire process of innovation development by answering problem formulated by farmers, and act as coordinators of innovation.

Agricultural extension staff can play an important role for the development of innovation. They support people engaged in agricultural production, and help them to solve problem. But currently, farmers complained about their effectiveness. Extension services should go beyond simply transferring knowledge they obtained during training to facilitation. Also, they should go beyond training and demonstration to learning. The extension services should be more demand-driven and participatory. Unfortunately, today's extension services in Benin are weak and only focus on wealthier farmers as they lack financial support.

FOs capacity in the future should also be strengthen so they can ask for the right type of services. Today, it is not FOs that demands something to international donors for training but the project comes and asks if they need that kind of training.

6.2.2. Linking the stakeholders: Partnership matter

Another important feature of an innovation system is the links between the stakeholders. Strengthening partnerships need time and resources. It is important to figure out what will be the right connection between which partners. The links between all the actors of the food chain, and of the food and farming systems need to be reinforce (NGO, industrialist, governmental services, farmers). The establishment of contract between different parties can provide better guarantee, and can favor innovation. Also, creating place to the exchange of knowledge and information between stakeholders is also crucial.

7. Conclusion

During the last decade, lots of projects linked with ISFM, using different approaches to research and development were launched in Benin. Some of them focused on the issue of food insecurity and poverty and other on the degradation of natural resources. The successful program associated technical innovation with social, organizational and institutional one. Also, the strength of the links between the different stakeholders determined the success of the innovation. The involvement of stakeholders with various knowledge and activities also played an important role in the development of innovation.

The limits for scaling-up of such initiatives were the problem of poverty and perverse policies. Indeed, the poverty trap in which smallholders' farmers are embedded hinders them to invest in SFM practices that require financial and human capacity. Also, national policies with subsidies import food prevent farmers' willingness to produce more and thus invest in soil fertility.

The lessons learnt from the case studies are that even if farmers hold knowledge about soil fertility management practices and possible strategies, they need to be well organized and strongly connected to output, input and finance markets to really improve their livelihood. It means that not only farmers need to have access to lots of different knowledge and information but they also need to be more organized (to facilitate the exchange of information and knowledge) and more market integrate (to make farming a living).

Thus, from the finding of the case studies, it seems important that national policies promote the use of participative approach, that strengthen farmers capacity and social network, but also facilitate their access to input, output and finance market.

Finally, as this study was only based on qualitative data, in order to thoroughly assess the impact of such initiatives on farmers' livelihood some quantitative data should be collected and analysed.

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Appendix 1: Description of main organic soil fertility practices in Sub-Saharan Africa (Place et al. 2003)

Organic practice	Description
Animal manure	The spread of solid and liquid excrement from animals, mainly cattle. Intensified livestock production systems involve the collection of manure in stalls or pens, while the more extensive systems involve direct deposition of manure by grazing animals.
Compost	The collection and distribution of a range of organic compounds that may include soil, animal waste, plant material, food waste, and even doses of mineral fertilizers. Prior to application of compost onto the field, there is a period of incubation to decompose materials.
Crop residues	The in situ utilization of crop residues. The utilization may be in the form of leaving residues on the surface or by cutting, chopping, and incorporation of crop residues into the soil. This operation is often done at the time of land preparation for the following season.
Natural fallow	Withdrawal of land from cultivation for a period of time to permit natural vegetation to grow on the plot. The breaking of the crop cycle and lead to regeneration and the fallows can also recycle nutrients.
Improved fallow	The purposeful planting of a woody or herbaceous plant to grow on a plot for a period of time. In addition to benefits of natural fallows, improved fallows can achieve equal impacts of natural fallows in shorter time periods because of purposeful selection of plants, such as those that fix atmospheric nitrogen.
Intercropping systems	Nutrient sources are integrated with crops in both time and space. The organic source may be a permanent feature on the plot such as with alley farming or scattered trees or may also be annual legumes. Intercrops are normally carefully planted, but trees in certain parkland systems (e.g. *Faidherbia albida*) are naturally growing.
Relay systems	Relay systems are similar in sharing space with the crop, but the organic source is planted at a different time than the crop and the timing of their primary growth period may differ.
Dual purpose legumes	These may be grown in intercrops or rotations with cereals. They thus maintain the features described above except that they also produce a second major product such as a grain for human consumption.
Biomass transfer	The transport and application of green organic material from its ex situ site to the cropping area. The organic source may be purposefully or naturally grown.

Appendix 2: Characteristics (agro-ecological and socio-economic) of the selected case study sites

Criteria	Characteristics		
	Ifangni - Plateau	Miniffi - Collines	Kouandé - Atacora
Agro-ecological Zone (INRAB classification)	“Terre de Barre”	“Zone cotonnière du centre Bénin”	“Zone vivrière du sud Borgou”
Climate	Subequatorial, 2 rainy season (1200mm/year)	Transition, 2 rainy seasons (800-1200mm/year)	Sudan-Guinean, one rainy season, 1000 to 1300mm/year)
Type of Soils	-Ferralitics (« terre de barre ») = *Ayigbavè* -Hydromorphic = *Ayigbayou*	-Tropical ferruginous -Vertisols -Hydromorphics	-Tropical ferruginous
Crops	Main crops: Maize, Cassava, Oil Palm, Vegetables Secondary crops: Cowpea, Groundnut, Pepper, Taro	Main crops: Maize, Cotton, Cassava, Soya Secondary crops: Groundnut, Cowpea, Yam, Rice	Main crops: Maize, Cotton, Yam, Soya, Cashew Secondary crop: Cowpea, Groundnut, Millet, Sorghum
Livestock	Small number: poultry, pork, small ruminant	Small number: poultry, small ruminant	Small number: small ruminant and poultry, and cattle as draught power
Land availability	Limited land availability – Demographic pressure (409people/km²)	Medium land availability – low demographic pressure (76 people/km2)	High land availability – very low demographic pressure (24 people/km2)
Access to land	Mainly purchasing – Breaking up of lands – also inheritance and lending	Inheritance, lending – low breaking up of lands	Inheritance, lending – low breaking up of lands
Access to mineral fertilizers	Limited – No cotton production	Good – Cotton production	Good – Cotton production
Access to organic material	Limited – Few livestock	Low – few livestock	Good – Livestock, animal traction and Peulhs

Access to credit	Limited - no cotton production or cash crop	Good - through cotton production	Good - through cotton production

Appendix 3: Study design – Research activity and process