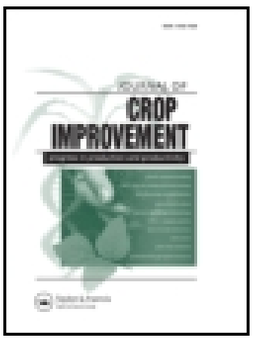

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Towards effective soybean seed systems in Benin: Current situation and prospects for production and delivery of good quality seed

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ABSTRACT

Facilitating farmers' access to quality seed requires proper understanding of the functioning of seed systems. This study aimed at analyzing soybean (*Glycine max* [L.] *Merr.*) seed systems in Benin to pave the way for strengthening this sector. The research approach consisted of desk research, focus group discussions, individual interviews and validation workshop with stakeholders involved in soybean seed systems. Our findings revealed that despite the existence of an institutional and organizational framework, the formal soybean seed system is not at all functioning. Farmers mainly relied on informal seed system through self-saved seed and seed purchase in the markets. There is an emerging soybean seed system led by NGOs and farmers' organizations. Current soybean seed systems are ineffective in timely supplying desired soybean varieties to farmers. Creation of enabling environment to attract private investment and develop local seed businesses is proposed along with new organizational arrangements among stakeholders. Farmers' training in seed production, processing and managerial skills, as strategy to improve informal seed system, are proposed to strengthen local seed business. Farmers' organizations have a critical role to play, as they serve as intermediary between their members and seed producers. Information and Communication Technology (ICT) could be exploited not only to promote improved seeds but also to ensure traceability in the system. Quality Declared Seed could be the most adapted quality insurance scheme in remote areas. The proposed arrangements among stakeholders in the seed systems in this study could be applied to legume crops other than soybean.

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KEYWORDS
Certification; information and communication technology; seed business; seed distribution; quality declared seed

Introduction

Soybean (*Glycine max* [L.] Merr.) is a multipurpose crop that plays an important role in improving soil fertility and enhancing food and nutritional security. Its value chains constitute an important source of income for rural

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populations in Africa (Baris et al. 2015; Kolapo 2011; Sinclair et al. 2014). In Benin, soybean-based products including milk, cheese, cake, and infantile flour offer a cheaper source of protein, as compared with fish and meat (Floquet et al. 2013). Soybean is also used as raw material in vegetable oil industry in the country and its by-product (press cake) is in high demand in feed milling, offering an additional market outlet for soybean farmers. Because soybean is a highly nutritious crop with high economic value, there has been a growing interest in soybean production in Benin as in many other West African countries (Wendland and Sills 2008). During the 2008–2015 period, Benin soybean production increased from 31,111 to 139,909 tons, but this was mainly achieved through expansion of area under soybean (from 37,042 ha in 2008 to 152,138 ha in 2015) (MAEP 2016). Soybean yield in the country averages 0.9 $t.ha^{-1}$, which is still very low compared with the expected yield of at least 2 $t.ha^{-1}$ (Sinclair et al. 2014).

One of the major factors constraining productivity of soybean in Benin is the unavailability of good quality soybean seed (Alliance-Soja 2013; Baris et al. 2015). Access to good quality seed is a key to enhancing crop productivity, survival of farming communities, conservation of germplasm and agro-biodiversity (Almekinders and Louwaars 2002; Coomes et al. 2015; McGuire and Sperling 2016; Mula et al. 2013; Richards et al. 2009). Thus, improved farmers' access to good quality seed has received attention of many development and technical assistance projects and programs (Coomes et al. 2015; McGuire and Sperling 2013).

Seed system refers to all the processes related to the development, conservation, production, storage and dissemination of varieties (Tripp 1997). Worldwide, especially in developing countries, there is a wealth of literature on seed systems (e.g., Almekinders and Louwaars 2002; Almekinders, Louwaars, and De Bruijn 1994; Almekinders and Thiele 2003; Coomes et al. 2015; McGuire and Sperling 2016; Okry et al. 2011; Sperling and McGuire 2010). These studies revealed that for most of the food crops, farmers primarily had access to seed through informal systems (saved seed, exchange with neighbors, family members, purchase in markets) and actors in the seed systems had complex interactions. Studies focused on seed systems in Benin include Zannou (2006) on cowpea and yam; Akpo et al. (2012) on oil palm, Baco et al. (2013) on yam; Achigan-Dako et al. (2014) on maize and Ayenan et al. (2015) on rice. These studies confirmed that seed systems varied according to crops, regions and farms, and that farmers used various channels to have access to seeds (Almekinders and Louwaars 2002). Thus, it is important to understand how seed systems function to be able to strengthen them (Sperling and Cooper 2004) for a given crop in a region.

Stakeholders involved in soybean seed systems in Benin and insight into their relationships are currently poorly understood. This may hamper interventions seeking to strengthen soybean seed systems. Thus, proper

understanding of the organizational and institutional arrangements underlying seed systems is deemed important.

The objectives of this study are to identify stakeholders involved in the soybean seed systems in Benin, to examine their roles and linkages, and analyze the functioning and the performance of the systems. This will lay the foundations for new organizational arrangements in order to boost good quality soybean seed production and supply.

Materials and methods

Exploratory phase

The entry point for data collection was the Agricultural Research Center (CRA-Nord), one of the research centers of the Institut National des Recherches Agricoles du Bénin (INRAB). The center is located in the municipality of Bembèrèkè (Figure 1). The CRA-Nord has, at national level, the mandate of producing soybean foundation seed. Using a snow ball technique, the contact with CRA-Nord helped in the identification of seed producers, Non-Governmental Organizations (NGOs) and farmers' organizations involved in soybean seed systems. This sampling technique consists in increasing the sample size beginning from a respondent who helps to identify other potential respondents (Biernacki and Waldorf 1981). This step enabled a quick mapping of participants to be interviewed during the in-depth survey.

In-depth study

A qualitative research approach through discussions with stakeholders involved in soybean seed systems and expert elicitation was used. Face-to-face interviews were conducted with experts from the Ministry of Agriculture [Ministère de l'Agriculture, de l'Elevage et de la Pêche (MAEP)]), the national coordinator of West African Seed Project (WASP), the country representative of International Fertilizer Development Center (IFDC), seed quality control and certification department [Service de la Promotion de contrôle de Qualité et du Conditionnement des produits agricoles (SPQC)]. In all, 10 experts were interviewed. The representatives of NGOs involved in soybean seed systems, namely Organisation pour le Développement Durable, le Renforcement et l'Autopromotion des Structures (DEDRAS), Centre de Recherches et d'Action pour le Développement des Initiatives à la Base (CRADIB), and Recherche et Action pour la Promotion des Initiatives de Développement Local (RAPIDEL), and Fédération des Unions des Producteurs du Bénin (FUPRO) were also interviewed. Six soybean seed

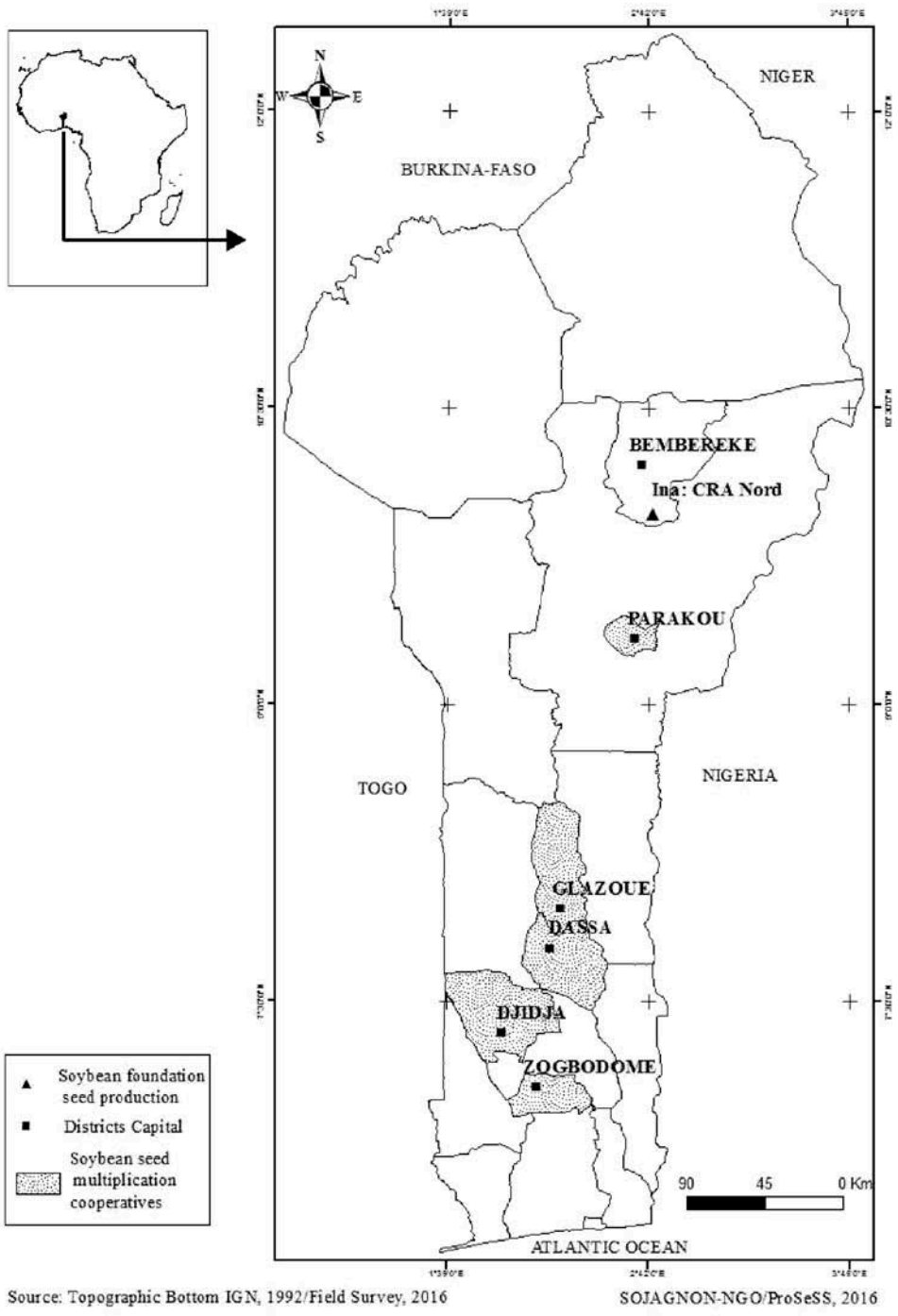

Figure 1. Map of Benin with locations of soybean seed multiplication cooperatives.

producers' cooperatives were identified (Figure 1). Three to four representatives of each cooperative were interviewed. Six focus group discussions with soybean seed producers were held. The following points were

addressed during discussions with experts, NGOs and farmers' organization representatives and seed producers:

(i) stakeholders involved in soybean seed systems;
(ii) relationship between the stakeholders;
(iii) organization of seed production and marketing systems;
(iv) institutional framework of soybean seed systems;
(v) participants' perception on the performance of the systems and factors hindering soybean seed production and supply and
(vi) strategies to set up sustainable and effective soybean seed systems.

Validation workshop

A validation workshop was organized with 18 participants, including seed producers (06), farmers' organizations (03), researchers (02), NGOs (03) and seed quality control and regulatory staff (04). The participants were invited on the basis of the involvement of their organization in soybean value chains in general, and in soybean seed systems in particular.

During the workshop, the results obtained from the various interviews (stakeholders and their role in the soybean seed systems, institutional framework for soybean seed systems) were presented and actors provided further inputs regarding the organization and functioning of soybean seed systems in Benin. Organizational arrangements for quality soybean seed production and marketing were proposed by stakeholders and thoroughly discussed. Flowcharts were used to represent current and desired organizational framework of soybean seed system.

Results and discussion

Three soybean seed systems were identified. The formal seed system, the informal seed system and the NGO-led seed system. It is worth noting that the formal seed system was found not to be functioning, but as in other crops, the organizational and institutional frame exist.

Formal soybean seed system

A national seed policy was adopted in 2015, along with an action plan for its implementation. The national seed policy aims to: (i) make available quality seeds to farmers at the appropriate time and affordable cost; (ii) create favorable environment for seed trade by reducing impediments to trade; (iii) create favorable environment for private investments in seed sector; (iv) promote public-private partnership and (v) reinforce institutional and legal framework of seed sector (MAEP 2015). In the national seed policy, the

roles of the various actors, namely, research institutions, support-services providers, farmers' organizations and private sector as well as government and regional organizations, in the formal seed system are specified.

Research institutions

Research institutions included the INRAB, universities, and International Agricultural Research Centers. The International Research Centers, especially International Institute of Tropical Agriculture (IITA), develop soybean varieties and send breeding materials to the INRAB, which produces the breeder and foundation seeds. Breeder and foundation seeds are produced under control of the directorate in charge of seed quality testing and certification. The INRAB is in charge of maintaining any variety registered in the national seed catalogue (Figure 2). Universities and the INRAB can also initiate their own breeding programs. However, neither the INRAB nor the universities had an ongoing soybean breeding program.

Farmers' organizations and private sector

Farmers' organizations and the private sector are responsible for producing certified seeds. For this purpose, they source foundation seeds from the INRAB. Certified seeds are produced under control of the seed quality control and certification department [Service de la Promotion de contrôle de Qualité et du Conditionnement des produits agricoles (SPQC)]. The NGOs and extension agents are involved in capacity building for seed producers to ensure their compliance to the regulations. Farmers' organizations and private sector are responsible for packaging and marketing their seeds (Figure 2).

Support services providers

Agencies provide support services, such as seed quality control, capacity building or financial assistance to direct actors in the seed system. Crop production directorate [Direction de Production Végétale (DPV)] is the permanent secretariat of the National seed committee. The directorate ensures the coordination of seed sector. The office identifies seed enterprises, contributes to dissemination of information on seed regulations and inspects seed multiplication plots (Figure 2). It is also actively involved in capacity building of seed producers.

Seed quality control and certification department [Service de la Promotion de contrôle de Qualité et du Conditionnement des produits agricoles (SPQC)] is also involved in field inspection, control and certification processes of all generations of seeds, including breeder seeds, foundation seeds and certified seeds. Certification fees, including field inspection and laboratory works, are subsidized by the government for rice and maize seeds but not for soybean seeds.

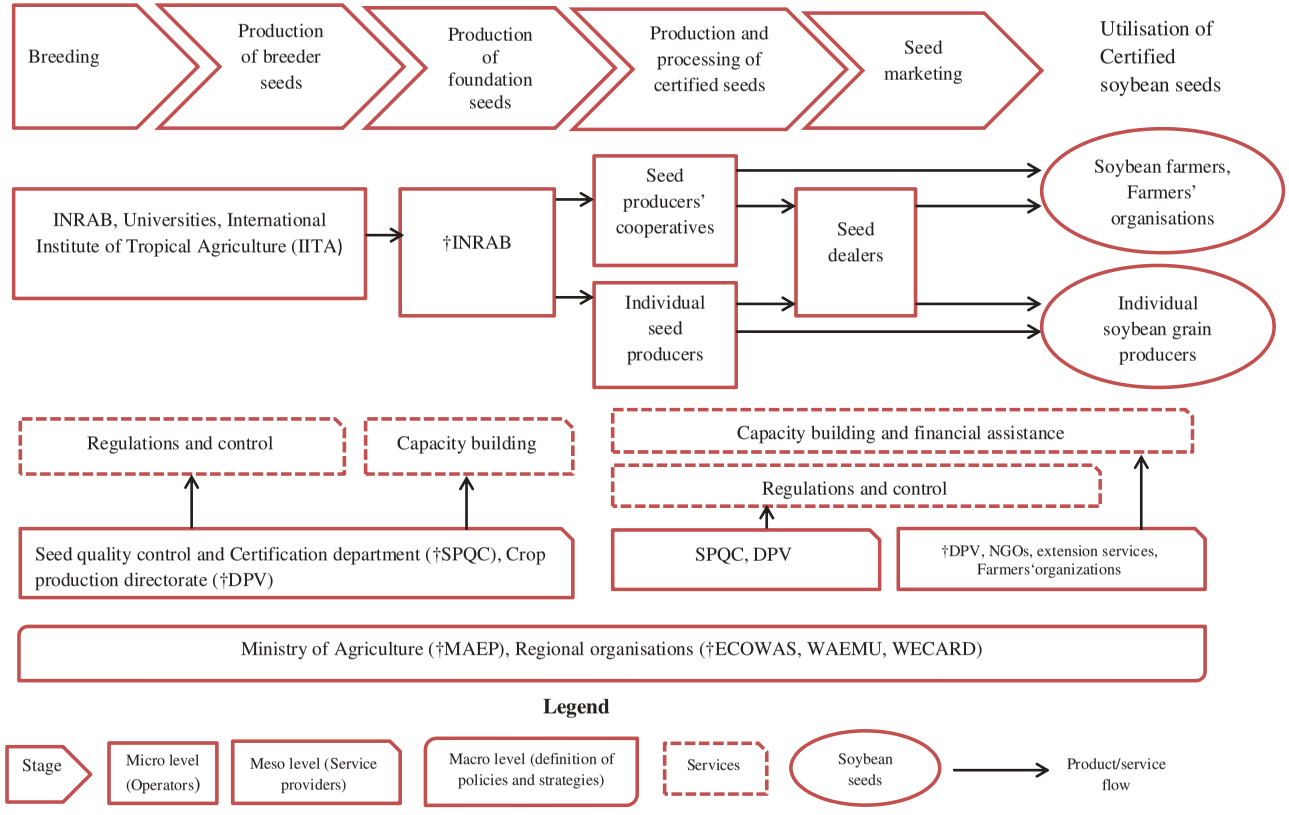

Figure 2. Organizational framework for formal soybean system in Benin.
†DPV = Direction de la Production Végétale
ECOWAS = Economic Community of West African States
INRAB = Institut National des Recherches Agricoles du Bénin
NGOs: Non-Governmental Organizations
SPQC: Service de la Promotion de contrôle de Qualité et du Conditionnement des produits agricoles
WECARD = Council for Agricultural Research and Development
WAEMU = West African Economic and Monetary Union

The office of information, innovation, agricultural advisory and operational training of the Ministry of agriculture (MAEP), NGOs and extension services are in charge of disseminating technology packages, promoting the use of certified and improved seeds. They also train farmers in seed production with the assistance of officers from seed quality control directorates.

Government and regional organizations

Three major regional organizations, including Economic Community of West African States (ECOWAS), West African Economic and Monetary Union (WAEMU), and Council for Agricultural Research and Development (WECARD), are not directly involved in the seed chain, but they make decisions that influence seed sector as a whole (Figure 2). These regional organizations operate at macro level by defining policies and strategies that shape the organization and functioning of seed systems in their member states. The current regional seed policy is reflected in the Agreement C/REG.4/05/2008 on harmonization of rules related to quality control, certification and marketing of seeds in the West African sub-region (ECOWAS 2008). The WECARD is currently implementing the West African Seed Program (WASP) and has developed an online platform (see http://www.wasix.net/) for seed marketing, which offers opportunities to link private seed companies to seed users.

In the formal seed system, the State was only responsible for seed production and distribution until 1995 when the sector was liberalized (Achigan-Dako et al. 2014; Maroya 2006). Consequently, farmers' organizations and private sector should play a key role in seed production and distribution (Achigan-Dako et al. 2014). Similar orientations in seed sector were observed in many African countries as a result of the structural adjustment programs (Louwaars and De Boef 2012). However, the liberalization of the seed sector has not attracted private investments, as expected because of poor organization of the sector and non-favorable environment for seed enterprises (Achigan-Dako et al. 2014; Maroya 2006). In addition, the State has been involved in seed delivery at low cost, making it impossible for seed enterprises to be competitive and survive (Achigan-Dako et al. 2014). Creating conducive environment for seed enterprises is a pre-requisite to attract private investment in the seed sector.

Informal soybean seed system

The informal soybean seed system consists of self-saved seeds/retained harvests, exchanges and gifts among relatives or other members of the community. Soybean seed exchange is based on mutual trust and contributes to strengthening of social ties among farmers. Soybean seed exchange is based on mutual trust and contributes to strengthen social ties among farmers. (Leclerc and d'Eeckenbrugge 2012, Bèye and Wopereis 2014). In the case of

soybean, farmers transmitted knowledge on production techniques while exchanging seeds. However, no soybean seed custodian was reported. Another source of seed in the informal system is seed purchase from local markets where there is no distinction between seeds and food grain. Farmers reported poor soybean seed quality when seeds are purchased from markets or obtained from fellow farmers. In fact, seeds purchased from the market or obtained from relatives or fellow farmers are often of unknown and non-reliable quality (Almekinders and Louwaars 1999).

The key actors of this system are farmers, traders and extension agents. Soybean is not a native crop in Benin (Shurtleff and Akiko 2009) and as such, all the cultivated varieties were introductions. These varieties have become part of the local seed network, but none of them is associated with cultural belief, symbolism or special use as compared with, for example, rice (*Oryza sativa* L.) (Pfeiffer et al. 2006) and Kersting's groundnut [*Macrotyloma geocarpum geocarpum* (Harms) Maréchal & Baudet] (Ayenan and Ezin 2016). Traders selling food grain are major seed disseminators among villages. Interview with experts revealed that this system was the most important source of soybean seeds for farmers, as it is for other crops in developing countries where more than 80% of the seeds are sourced from the informal seed systems (Almekinders and Louwaars 2002; Bèye and Wopereis 2013; Hirpa et al. 2010; Holmesheoran et al. 2012; McGuire and Sperling 2016; Mubangizi et al. 2012; Richards et al. 2009).

In the field, as in storage, farmers generally do not separate seeds from food grain. This is a typical characteristic of informal system as farmers produce seed as an integral part of their production systems and not as distinct activity (Sperling and Cooper 2004). Seed storage in same conditions as food grains might contribute to poor soybean seed quality, as mentioned by farmers. In fact, soybean seed viability and vigor are highly sensitive to humidity and temperature (Adebisi et al. 2004). Thus, soybean seeds should be stored and processed under appropriate conditions (controlled seed moisture content, temperature and relative humidity) (see Hayma 2003). This may be an opportunity for local seed businesses, which can mobilize resources for adequate production and storage, to take over production of soybean seeds.

Planting materials in this system are mixtures of seeds of recycled, improved varieties. This practice, common in informal seed systems, caused problems in timing of harvest (Hirpa et al. 2010). In addition, mixture of soybean varieties may prevent farmers from meeting quality standards required by processors who are interested in a given soybean variety and not in a mixture of varieties. Lammerts Van Bueren (2011) raised a similar concern about using mixture of wheat varieties because of the negative effect on the homogeneity of the product. On the other hand, the use of mixed varieties is supposed to lower the risk of crop failure. In fact, variety mixtures are made up of different varieties with various adaptation potential to environmental conditions, including pest and disease pressure, low soil fertility and low rainfall (Finckh

et al. 2000). In the light of these findings, farmers should be trained to maintain genetic purity of their varieties to facilitate agricultural operations (e.g., harvesting) and to meet market demand unless they deliberately mix their varieties to adapt to environmental stress.

During demonstration trials, extension agents provide selected farmers with seeds of new soybean varieties free of charge. Through seed exchange, the new varieties are passed on to other farmers. This practice favors the dissemination of new materials and it helps widen germplasm base available to farmers (Bèye and Wopereis 2013; Okry et al. 2011). As evidenced in this study, the informal soybean seed system has remained dominant and it should be considered in seed regulations and policies (Bèye and Wopereis 2013; Louwaars, De Boef, and Edeme 2013).

NGO-led soybean seed system

The NGO-led soybean seed system was initiated by local NGOs and farmers' organizations. As with community-based seed system, it is a development-oriented system as it is not driven by potential for profit, but it is rather guided by the need to develop and ensure wide diffusion of improved varieties (Diallo and Gildemacher 2013). Seed production is undertaken by farmers' cooperative as a discrete activity.

Several institutions, including international research and national public institutions, NGOs, farmers' organizations and seed producers, are involved in the NGO-led soybean seed system (Figure 3). In this system, the International Institute of Tropical Agriculture (IITA) develops soybean varieties (Table 1) and releases them through the national agricultural research institute, which is in charge of producing foundation seeds. The farmers' organization (FUPRO) and NGOs primarily source foundation seed from the agricultural research center (CRA Nord). The FUPRO and NGOs supply the foundation seeds to the seed producers' cooperatives they support. In addition, technical and financial (input credit) assistance is provided by FUPRO and NGOs to the seed producers to ensure that they comply with seed-production practices. At harvest, the seeds go through quality-control process undertaken by a representative of the crop quality control directorate at the municipality level. Germination test and physical purity assessment (absence of foreign matters and off-type seeds) are the main criteria used to assess soybean seed quality. Once seeds are declared to be of good quality, farmers sell them to their organization. Farmers' organizations and NGOs ensure storage, conservation and marketing of soybean seeds and the profit made is used to pay certification fees.

This system ensures a minimum standard of seed quality. Nevertheless, it covers only about 1% of soybean seed demand (Table 2). In addition, concerns are raised about its sustainability as support provided by NGOs and farmers' organizations is based on grants received from donors. Several

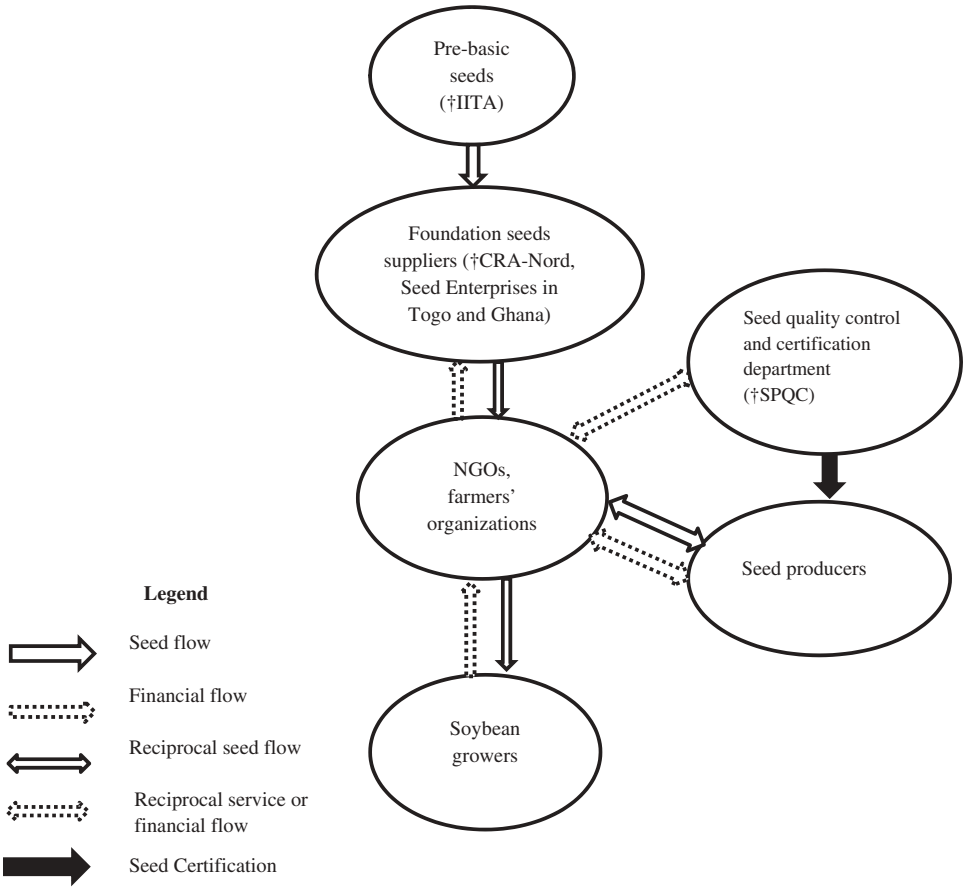

Figure 3. NGO-led soybean seed system.
†CRA-Nord: Agricultural Research Center
IITA = IITA International Institute of Tropical Research
NGO = Non-Governmental Organization
SPQC = Service de la Promotion de contrôle de Qualité et du Conditionnement des produits agricoles

Table 1. Cultivated soybean varieties in Benin and their characteristics.

Varieties	Characteristics	Status of production	Origin†
TGX1910-10F	Pulses are resistant to shattering, cycle: 105 days, on farm yield (1.7 t/ha), large grains	Increasing	IITA
TGX 1910–14F	Non-dehiscent pulses, cycle: 105 days, on farm yield (2t/ha), large grains	Increasing	IITA
TGX1830-20E	Pulses are moderately resistant to shattering, early maturing (90 days), on farm yield (1.2t/ha), large grains	Newly introduced	IITA
TGX1448-2D	Non-dehiscent pulses, cycle: 105 days, on farm yield (1.3t/ha), large grains	Increasing	IITA
Jengouman	Pulses are resistant to shattering, cycle: 105 days, large grains	Increasing	Ghana
Jupiter	Pulses are highly susceptible to shattering, late maturing (120 days), 800 kg/ha, small grains	Decreasing	IRAT

†IITA = International Institute of Tropical Research.
IRAT = Institut de recherches agronomiques tropicales et des cultures vivrières.
Source: CRA-Nord, 2016. Yields were obtained from on-farm trials conducted by CRA-Nord.

Table 2. Quantity of soybean certified seeds produced through †NGO-led system from 2011 to 2015.

Years	Amount of soybean seeds produced	% of total soybean seed needed
2011	24,000	0.32
2012	45,000	0.56
2013	36,000	0.38
2014	60,000	0.61
2015	100,000	0.66

Adapted from statistics of the Agricultural Research Center CRA-INA.
†NGO = Non-Governmental Organization.

studies in developing countries have reported the abandonment of seed production by farmers when inputs and support provided by projects end (Almekinders and Thiele 2003; Okry et al. 2011). Sustainability of the system will depend on the capacity and the motivation of farmers to pursue their seed production activity at the end of the projects. This will be possible if farmers embrace seed production as a business in which they would be willing to invest.

Information flow in soybean seed systems

Seed producers expressed the need for information on yield potential of varieties, growth cycle and pod resistance to dehiscence. Findings revealed that in the NGO-led system, seed producers had access to requested information because of their interaction with researchers, NGOs and farmers organizations during trainings and varietal trials. In the informal system, however, access to information from supporting organizations (NGO, researchers, farmers' organizations) is limited and the main sources of information for farmers on soybean varietal traits are fellow farmers, and soybean sellers.

Information flow in the soybean seed systems is mainly one way, either from supporting organizations to farmers or from seller to farmers. An effective information flow in seed systems should also enable researchers, NGO and farmers' organizations to get feedback from farmers on the performance of varieties and their varietal preferences. In addition, information on new varieties and seed stock (seed availability and location of suppliers) would enhance farmers' access to quality seed (Sperling, Boettiger, and Barker 2014).

The use of Information and Communication Technology (ICT) in technology dissemination in rural areas is gaining interest (Maumbe and Patrikakis 2013; Mittal 2001; Muriithi, Bett, and Ogaleh 2009). Disseminating information on new varieties to reach more farmers with minimum cost involved can be done through the use of ICT. That may require the design of a database, including the phone numbers of farmers,

especially those who are members of farmers' organizations. Targeted text messages, using Short Message Service (SMS), in local languages can be sent to farmers to keep them updated on new varieties and their traits. In collaboration with mobile network providers, this system can evolve to the development of an application, operating without Internet connectivity, whereby farmers can request information on varieties and get instant results. Quality and timely information on improved varieties, seed sales points and their price will help farmers make informed decisions. Farmers who are connected to the researchers and/or seed enterprises will serve as entry point for the information in the community. The information can then be spread by word of mouth. Such a system is being implemented to deliver cowpea seeds in Benin (Authors' personal observation) and in Kenya by a seed company, resulting in increased adoption of improved varieties (Muriithi, Bett, and Ogaleh 2009). Participatory varietal selection, combined with on-farm field trials and demonstration by involving stakeholders along the seed value chain (farmers, processors, regulatory agency, extension officers, researchers and seed enterprises), is also an excellent strategy for the diffusion of improved seed (Bèye and Wopereis 2013; Witcombe 1996).

Organizational arrangements for sustainable production of good quality soybean seeds

Seed systems being implemented in Benin rely heavily on external funding through either direct supply of foundation seeds to seed producers or by supporting the certification fees. Participants at the workshop proposed a soybean seed-production and distribution model (Figure 4) based on existing competences in seed production. Pending the start of a soybean breeding program in Benin, introduction of varieties will remain the main source for farmers to have access to improved seeds. Varieties identified for introduction should be evaluated for adaptability and stability across different agro-ecological zones, and their preferences by farmers and consumers should be assessed before proposing them to the variety release committee.

The involvement of public sector in soybean seed is limited to the production of foundation seeds. To produce and supply quality seed to farmers, an enabling environment should be created to attract private operators. Thus, the State should avoid competing with private operators by selling subsidized seeds or distribute seeds for free. Measures against counterfeit labeling should also be taken and enforced to protect private investment. In addition, research institutions and extension officers should create and strengthen linkages with private operators who have business and advertisement skills to raise farmers' awareness on the use of improved varieties and quality seeds.

The government can also provide private seed enterprises, willing to operate in the soybean seed sector, with incentives (*e.g.*, taxes, subsidies on

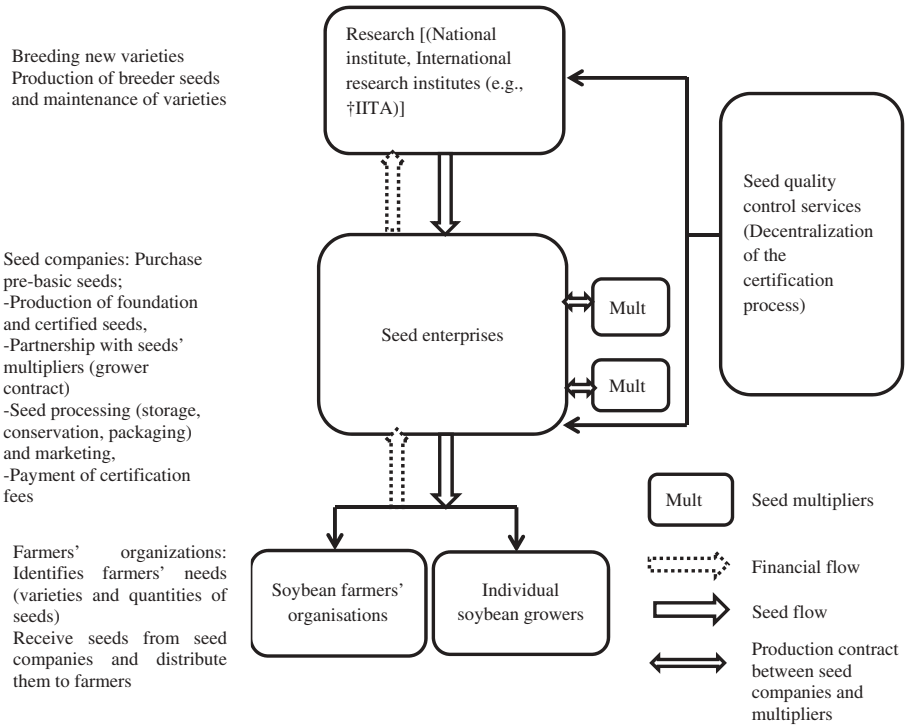

Figure 4. Soybean seed production and distribution model proposed by stakeholders. †IITA = International Institute of Tropical Research.

inputs and services) (MAEP (Ministère de l'Agriculture, de l'Elevage et de la Pêche) 2015). In Nigeria, some private seed enterprises pay little or no tax on imports and the Seed Council provides them with subsidized training and quality control. This helps them keep their overhead costs low (Bentley, Ajayi, and Adelugba 2011). However, inconsistency of the government in providing the subsidy for one reason or another would negatively affect planning of seed enterprises as they would be relying on the subsidies. Thus, if subsidies can help seed enterprises to expand or strengthen their activities, they should not be regarded as a basis for seed business model.

The seed enterprises may adopt a grower contract/out-grower schemes whereby they contract with seed producers' cooperatives or individual seed multipliers, who will conduct seed multiplication under supervision of the private enterprises. The enterprises will buy produced seeds for processing, packaging, labeling and marketing. The enterprises should commission seed quality control agencies for certification. The certified and labeled seeds can then be sold to farmers' organizations or individual soybean farmers. The out-grower schemes in seed sector have been successfully implemented by enterprises, for instance, in Zimbabwe (Setimela, Monyo, and Bänziger 2004), in Nigeria (Bentley, Ajayi, and Adelugba 2011) and in Uganda (Van

Mele et al. 2011). These experiences revealed that farmers are willing to produce seeds and maintain the contracts with seed enterprises since they have a market outlet for their produce.

The role of farmers' organizations is critical in the functioning of this system. They have to identify the need of their members relative to varietal traits and help estimate their demand (Figure 4). This will inform seed producers on the market needs and the quantity of seeds needed. This is important to plan seed production to cope with fluctuating demand. For better integration of farmers' organizations in the seed production and distribution system, they should be given incentives, such as a negotiated percentage of the income from seed sales. The amount will be jointly set with the seed enterprises. Doing so would motivate farmers to market seeds and promote the use of improved varieties and quality seeds in their community. Similar arrangement is ongoing for cowpea seeds in Benin, which has yielded encouraging results (Authors' personal observation).

To assure seed availability to farmers and also secure a market for seeds, a pre-ordering system may be developed by seed enterprises. Thus, certified seeds will be produced by the seed enterprises after receiving an order and an advance payment from farmers' organizations. A similar model was reported in Mali and it has the advantage of lowering production risk (over-production or seed shortage) (Diallo and Gildemacher 2013). Seeds will be distributed in small packs (500 g to 5 kg), along with leaflets containing information on variety names, growth cycle, potential yield, and tolerance to diseases. This distribution technique enables farmers to make informed varietal choice and it has been proven useful in reaching a large number of farmers through various supply channels (David and Sperling 1999; McGuire and Sperling 2013; Setimela, Monyo, and Bänziger 2004). Certified seed cost, which is a key component of seed affordability, was not addressed in the proposed arrangement. Further investigation in this regards should address farmers' willingness to pay for certified seeds in order for seed enterprises to adopt a competitive pricing policy.

Distribution of seed in small packs (500–5 kg) along with rhizobia inoculant is an opportunity for both inoculant and seed producers. Seed-coating technology using rhizobia inoculum is being promoted in Benin (Donou 2015) and it could serve as driving factor for the adoption of improved seeds. Seed enterprises can partner with the existing rhizobia inoculum production unit to coat their seed that will be distributed in the small packs. The planting of quality seeds coated with inoculant would help maximize varietal yield potential. Doing so will make the use of improved seed and inoculum cost-effective (Ravinder Reddy et al. 2007).

How to integrate the formal and informal soybean seed systems?

Stakeholders agreed on the fact that the proposed model, which represents only the formal system, cannot reach farmers in some remote areas (villages far from capital district). The formal seed system has the advantage of developing new and improved varieties, but it is limited in its ability to disseminate these varieties to farmers, especially in remote and/or marginalized areas (Setimela, Monyo, and Bänziger 2004). Currently, the relationship between research institutions and farmers' organizations is weak and not formal. For this purpose, it is important to strengthen the linkage between farmers' organizations and research institutions through, for instance, participatory varietal selection.

The primary aim in this system is to enable farmers to have access to improved varieties while producing, saving and re-using their seeds. Farmers, who are willing to engage in seed production and marketing in these areas, should register with seed quality control services and receive training in seed production. In remote areas and marginalized areas, seed quality control officers have limited access to farmers and they can only perform minimum control. The production of "Quality Declared Seed (QDS)" can be promoted (FAO 2006) with appropriate labels. To ensure quality and traceability of seeds in the system, a few farmers can be identified in the community and trained to help seed quality control officers in field monitoring. Using ICT, quality control farmers will frequently interact with seed quality control officers and give update on seed production fields (presence of weeds, off-type, disease outbreak, pests attack, etc.). This will enable seed quality control officers to make fact-based decisions on fields and subsequently on seeds that should be approved as QDS. However, regulatory framework to market QDS is needed because the current seed policy and regional harmonization framework (MAEP (Ministère de l'Agriculture, de l'Elevage et de la Pêche) 2015; ECOWAS 2008) do not have any provision related to QDS. Lessons can be learnt from Uganda, Zambia and Tanzania where smallholders are allowed to produce and market QDS (CABI 2014).

Farmers should be trained in seed production, processing and marketing, with emphasis on quality standards. This can be done by extension agents. It is worth noting that training farmers in seed production to produce quality seed has not always been sustainable. However, success stories have been reported from some projects aiming at training farmers in seed production in Namibia (Setimela, Monyo, and Bänziger 2004), Malawi (Centre for Public Service Innovation 2007) and Mali (ICRISAT 2012). Thus, individual farmers or farmers' cooperatives have even become professional seed producers and are running viable seed enterprises. Training farmers in seed production should be combined with the development and strengthening of their managerial skills for efficient

production planning and marketing (Guei et al. 2011). This is particularly important for farmers who want to engage in seed production as a commercial activity. Farmers' business school, which is being promoted by farmers' organizations supported by technical partners, is an opportunity to strengthen farmers' skills in seed production and marketing.

Conclusion

The analysis of soybean seed systems provides better insight into the existing soybean seed systems, their constraints and opportunities that can be leveraged for their development. Soybean seed systems are composed of an NGO-led soybean seed system and the dominant informal seed system. Various stakeholders, including researchers, farmers, traders, NGOs and extension agents, are involved in these systems. From stakeholders' perspective, none of these systems is satisfactory in production and delivery of quality seed. Reaching the stage of well-established and flourishing seed enterprises will take some time. In the short term, priority should be given to introduction of new varieties along with implementation of participatory varietal selection to raise farmers' awareness about the use of improved varieties and good quality seed. Concomitantly, training of farmers in seed production and managerial skills have been suggested to strengthen the informal system and gradually integrate both formal and informal systems in the mid-term. In the long term, individual or farmers' cooperative involved in the seed business are expected to emerge as local private seed enterprises and develop a vertical integration with other farmers. Other private operators can also integrate and operate within the system. Making use of information and communication technology will be key in seed diffusion and in improving information flow in the seed system as a whole.

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References

Achigan-Dako, E. G., A. C. Houdegbe, M. Glèlè, and R. Nono-Womdim. 2014. Analyse du système de production et de distribution des semences de maïs (*Zea mays* L.) au Sud-Bénin. *Biotechnology, Agronomy and Society and Environment* 18 (1):49–60.

Adebisi, M. A., I. O. Daniel, and M. O. Ajala. 2004. Storage life of soybean (Glycine Max L. Merril) seeds after seed dressing. *Journal of Tropical Agriculture* 42 (1–2):3–7.

Akpo, E., P. V. Vissoh, R. C. Tossou, T. Crane, D. K. Kossou, P. Richards, T. J. Stomph, and P. C. Struik. 2012. A participatory diagnostic study of the oil palm (Elaeis Guineensis) seed system in Benin. *NJAS - Wageningen Journal of Life Sciences 60–63* 60–63:15–27. doi:10.1016/j.njas.2012.06.003.

Alliance-Soja. 2013. *Rapport du Forum autour des innovations sur le soja et le renforcement des liens entre les acteurs. Report*. Bohicon, Benin: Alliance Soja.

Almekinders, C., and N. Louwaars. 1999. *Farmers' seed production: New approaches and practices*. London, United Kingdom: Intermediate Technology Publications, Ltd.

Almekinders, C., and G. Thiele. 2003. What to do with the seed for small-scale farmers after all? *Cultivos Tropicale* 24 (4):5–8.

Almekinders, C. J. M., and N. P. Louwaars. 2002. The importance of the farmers' seed systems in a functional national seed sector. *Journal of New Seeds* 4 (1–2):15–33. doi:10.1300/J153v04n01.

Almekinders, C. J. M., N. P. Louwaars, and G. H. De Bruijn. 1994. Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica* 78 (3):207–16. doi:10.1007/BF00027519.

Ayenan, M. A. T., and V. A. Ezin. 2016. Potential of kersting's groundnut [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] and prospects for its promotion. *Agriculture & Food Security* 5:10. doi:10.1186/s40066-016-0058-4.

Ayenan, M. A. T., A. Saïdou, F. Quenum, E. L. Ahoton, and I. Balogoun. 2015. Système de production de semences certifiees de riz dans la Commune de Glazoué Au Centre du Bénin. *Annales Des Sciences Agronomiques* 19 (2):489–505.

Baco, M. N., I. Moumouni, A. K. Saka, R. A. Dossou, J. Egah and E. A. Asiedu. 2013. Entre semences paysannes et améliorées: exigences sociotechniques et avantages économiques de la minifragmentation de l'igname au Bénin. *Bulletin de la Recherche Agronomique du Bénin (BRAB)* 74:17–26.

Baris, P., D. Lagandré, A. C. Gogan, M. Gandonou, and M. Afomasse. 2015. *Etude de faisabilite du projet d'appui au developpement des filieres proteiniques (PADEFIP)*. Nogent sur Marnes, France: Gret.

Bentley, J. W., O. Ajayi, and K. Adelugba. 2011. Nigeria : Clustered seed. In *African seed enterprises*, edited by P. Van Mele, J. W. Bentley, and R. G. Guéi, 38–64. Wallingford, United Kingdom: Centre for Agricultural Bioscience International (CABI).

Bèye, A. M., and M. C. S. Wopereis. 2014. Cultivating knowledge on seed systems and seed strategies: Case of the rice crop. *Net Journal of Agricultural Science* 2 (1):11–29.

Biernacki, P., and D. Waldorf. 1981. Snowball sampling: Problems and techniques of chain referral sampling. *Sociological Methods Research* 10 (2):141–63. doi:10.1177/004912418101000205.

CABI Centre for Agricultural Bioscience International (CABI). 2014. Good Seed Initiative a strategy for CABI-led work on seed systems in Sub-saharan Africa and South Asia, 2014-2019. http://www.cabi.org/Uploads/seed%20(1).pdf

Centre for Public Service Innovation (CPSI). 2007. Community-based seed production: Limpopo farmers' strategy to resist drought. http://unpan1.un.org/intradoc/groups/public/documents/CPSI/UNPAN026456.pdf

Coomes, O. T., S. J. McGuire, E. Garine, S. Caillon, D. McKey, E. Demeulenaere, D. Jarvis, G. Aistara, A. Barnaud, P. Clouvel, L. Emperaire, S. Louafi, P. Martin, F. Massol, M. Pautasso, C. Violon, and J. Wencélius. 2015. Farmer seed networks make a limited contribution to agriculture? four common misconceptions. *Food Policy* 56:41–50. doi:10.1016/j.foodpol.2015.07.008.

David, S., and L. Sperling. 1999. Improving technology delivery mechanisms: Lessons from bean systems research in Eastern and Central Africa. *Agriculture and Human Values* 16:381–88. doi:10.1023/A:1007603902380.

Diallo, G. M., and P. Gildemacher. 2013. *Mali seed entrepreneurship assessment. ISSD briefing note*. Wageningen, the Netherlands: Centre for Development Innovation of Wageningen University and Research centre.

Donou, H. M. T. 2015. Rapport du cocktail d'affaire autour des technologies en diffusion par le PURRA-FUPRO. http://images.agri-profocus.nl/upload/post/Rapport_Cocktail_d'%C3%A9change_PURRA1449669983.pdf

ECOWAS. 2008. *Regulation C/REG.4/05/2008 on harmonization of the rules governing quality control, certification and marketing of plant seeds and seedlings in ECOWAS*. Abuja, Nigeria: ECOWAS. http://www.coraf.org/wasp2013/wp-content/uploads/2013/07/Regulation-seed-ECOWAS-signed-ENG.pdf.

FAO (Food and Agriculture Organization of the United Nations). 2006. Quality declared seed system. Paper 185. Rome, Italy: FAO. ftp://193.43.36.93/docrep/fao/009/a0503e/a0503e00.pdf

Finckh, M., E. Gacek, H. Goyeau, C. Lannou, U. Merz, C. Mundt, L. Munk, J. Nadziak, A. C. Newton, C. de Vallavieille-Pope, and M. S. Wolfe. 2000. Cereal variety and species mixtures in practice, with emphasis on disease resistance. *Agronomie* 20 (7):813–37. doi:10.1051/agro:2000177.

Floquet, A., A. Michaud, G. T. Vodouhè, and B. Bridier. 2013. *Appropriation du soja et de ses derives dans l'alimentation humaine et animale : Fruit de processus foisonnants et discontinus d'innovations*. Abomey-Calavi, Benin: JOLISAA CCA, Université d'Abomey-Calavi.

Guei, R. G., A. Barra, and S. Drissa. 2011. Promoting smallholder seed enterprises: quality seed production of rice, maize, sorghum and millet in northern Cameroon. *International Journal of Agricultural Sustainability*, 9 (1):91–99.

Hayma, J. 2003. *The storage of tropical agricultural products*. 4th ed, edited by S. Van Otterloo-Butler. Wageningen, the Netherlands: Agromisa Foundation.

Hirpa, A., M. P. M. Meuwissen, A. Tesfaye, W. J. M. Lommen, A. O. Lansink, A. Tsegaye, and P. C. Struik. 2010. Analysis of seed potato systems in Ethiopia. *American Journal of Potato Research* 87 (6):537–52. doi:10.1007/s12230-010-9164-1.

Holmesheoran, M. E., M. G. Mula, R. P. Mula, and K. B. Saxena. 2012. Tropical legumes 2 pigeonpea seed system in India: An analysis. *Journal of Food Legumes* 25 (4):334–39.

ICRISAT (International Crop Research Institute of the Semi-Arid Tropics). 2012. Mali: Sowing the seeds of success. http://library.cgiar.org/bitstream/handle/10947/2647/Mali_Sowing_the_Seeds_of_Success.%20pdf?sequence=1

Kolapo, A. 2011. Soybean: Africa's potential Cinderella food crop. In *Soybean - Biochemistry, chemistry and physiology*, edited by N. Tzi-Bun. Rijeka, Croatia: InTechOpen. 10.5772/15527. http://www.intechopen.com/books/soybean-biochemistry-chemistry-and-physiology/soybean-africa-s-potential-cinderella-food-crop

Lammerts van Bueren, E. T., S. S. Jones, L. Tamm, K. M. Murphy, J. R. Myers, C. Leifert, and M. M. Messmer. 2011. The need to breed crop varieties suitable for organic farming, using wheat, tomato and broccoli as examples: A Review. *NJAS - Wageningen Journal of Life Sciences* 58 (3–4):193–205. doi:10.1016/j.njas.2010.04.001.

Leclerc, C., and C. G. D'Eeckenbrugge. 2012. Social organization of crop genetic diversity. The G × E × S Interaction model. *Diversity* 4:1–32.

Louwaars, N. P., and W. S. De Boef. 2012. Integrated seed sector development in africa : A conceptual framework for creating coherence between practices, programs, and policies. *Journal of Crop Improvement* 26 (1):39–59. doi:10.1080/15427528.2011.611277.

Louwaars, N. P., W. S. De Boef, and J. Edeme. 2013. Integrated seed sector development in Africa: A basis for seed policy and law. *Journal of Crop Improvement* 27 (2):186–214. doi:10.1080/15427528.2012.751472.

MAEP (Ministère de l'Agriculture, de l'Elevage et de la Pêche). 2015. *Projet de document actualisé de politique semncière nationale au bénin*. Cotonou, Benin: MAEP.

MAEP (Ministère de l'Agriculture, de l'Elevage et de la Pêche). 2016. *Rapport annuel de la direction de la statistique agricole du ministère de l'agriculture, de l'elevage et de la pêche*. Cotonou, Benin.

Maroya, N. G. 2006. Vers la création d'une association nationale de producteurs et distributeurs de semences au bénin. *Bulletin Du Réseau Sur Les Semences En Afrique Occidentale (WASNET)* 16:2–6.

Maumbe, B. M., and C. Z. Patrikakis. 2013. *E-Agriculture and Rural Development: Global Innovations and Future Prospects*. Pennsylvania, USA: IGI Global.

McGuire, S., and L. Sperling. 2016. Seed systems smallholder farmers use. *Food Security* 8 (1):179–95. doi:10.1007/s12571-015-0528-8.

McGuire, S., and L. Sperling. 2013. Making seed systems more resilient to stress. *Global Environmental Change* 23 (3):644–53. doi:10.1016/j.gloenvcha.2013.02.001.

Mittal, S. C. 2001. Role of information technology in agriculture and its scope in India. *Fertilizer News* 46 (12):83–87.

Mubangizi, E., D. N. Ntamu, W. M. Thembo, and M. Thijssen. 2012. *Uganda seed sector assessment, ISSD Briefing note*. Wageningen, the Netherlands: Centre for Development Innovation of Wageningen University and Research centre.

Mula, M. G., K. B. Saxena, P. Gaur, and H. Upadhyaya. 2013. Legumes seed system in Asia: A case in India. In *Expert consultation workshop on community seed production*, edited by C. O. Ojiewo, S. Kugbei, Z. Bishaw, and J. C. Rubyogo. Workshop Proceedings 9–11 December, 2013. 65–70. Rome, Italy: FAO and Addis Ababa, Ethiopia: ICRISAT. http://www.fao.org/3/a-i4553e.pdf and http://oar.icrisat.org/8793/1/Ethiopia%20paper%20on%20seed%20system%20Dec%202013.pdf.

Muriithi, A. G., E. Bett, and S. A. Ogaleh. 2009. Information technology for agriculture and rural development in Africa: Experiences from Kenya. Paper presented at the Conference on International Research on Food Security, Natural Resource Management and Rural Development. University of Hamburg, October 6–8, 2009. http://www.tropentag.de/2009/abstracts/full/740.pdf.

Okry, F., P. van Mele, E. Nuijten, P. C. Struik, and R. L. Mongbo. 2011. Organizational analysis of the seed sector of rice in Guinea: Stakeholders, perception and institutional linkages. *Experimental Agriculture* 47 (1):137–57. doi:10.1017/S001447971000089X.

Pfeiffer, J. M., S. Dun, B. Mulawarman, and K. J. Rice. 2006. Biocultural diversity in traditional rice-based agroecosystems: Indigenous research and conservation of mavo (*Oryza sativa* L.) upland rice landraces of eastern Indonesia. *Environment, Development and Sustainability* 8:609–25. doi:10.1007/s10668-006-9047-2.

Ravinder Reddy, C., V. A. Tonapi, P. G. Bezkorowajnyj, S. S. Navi, and N. Seetharama. 2007. *Seed system innovations in the semi-arid tropics of Andhra Pradesh*. Patancheru, Andhra Pradesh, India: International Livestock Research Institute (ILRI), ICRISAT.502 324

Richards, P., M. De Bruin-Hoekzema, S. G. Hughes, C. Kudadjie-Freeman, S. Offei, P. Struik, and A. Zannou. 2009. Seed systems for African food security: Linking molecular genetic analysis and cultivator knowledge in West Africa. *International Journal of Technology Management* 45 (1/2):196–214. doi:10.1504/ijtm.2009.021528.

Setimela, P. S., E. Monyo, and M. Bänziger, eds. 2004. *Successful community-based seed production strategies*. Mexico, D.F.: CIMMYT.

Shurtleff, W., and A. Akiko. 2009. *History of soybeans and soyfoods in Africa (1857–2009): Extensively annotated bibliography and sourcebook*. Lafayette, CA, USA: Soyinfo Center.

Sinclair, T. R., H. Marrou, A. Soltani, V. Vadez, and K. C. Chandolu. 2014. soybean production potential in Africa. *Global Food Security* 3 (1):31–40. doi:10.1016/j.gfs.2013.12.001.

Sperling, L., S. Boettiger, and I. Barker. 2014. Integrating seed systems planning for scale brief # 3AgPartnerXChange. *Policy Brief*. http://seedsystem.org/wp-content/uploads/2014/03/Integrating-Seed-Systems-.pdf

Sperling, L., and D. Cooper. 2004. Understanding seed systems and strengthening seed security: A background paper. In *Towards effective and sustainable seed relief activities*, edited by L. Sperling, T. Osborn, and D. Cooper. 7–33. Rome, Italy: FAO. Plant Production and Protection Paper 181.

Sperling, L., and S. J. McGuire. 2010. Persistent Myths about emergency seed aid. *Food Policy* 35 (3):195–201. doi:10.1016/j.foodpol.2009.12.004.

Tripp, R. 1997. *New seed and old laws: Regulatory reform and the diversification of national seed systems*. London, United Kingdom: Intermediate Technology Publications, Ltd.

van Mele, P., M. A. Ugen, D. Wanyama, R. Anyang, J. C. Rubyogo, and L. Sperling. 2011. Uganda: Dreams of starting a company. In *African seed enterprises*, edited by P. Van Mele, J. W. Bentley, and R. G. Guéi, 156–80. Wallingford, United Kingdom: Centre for Agricultural Bioscience International (CABI).

Wendland, K. J., and E. O. Sills. 2008. Dissemination of food crops with nutritional benefits: Adoption and disadoption of soybeans in Togo and Benin. *Natural Resources Forum* 32 (1):39–52. doi:10.1111/j.1477-8947.2008.00169.x.

Witcombe, J. R. 1996. Participatory approaches to plant breeding and selection. *Biotechnology and Development Monitor* 29:26–32.

Zannou. 2006. Socio-Economic, Agronomic and molecular analysis of yam and cowpea diversity in the Guinea transition zone of Benin. PhD Thesis, Wageningen University & Research Centre.