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Review

# Cultivating knowledge on seed systems and seed strategies: Case of the rice crop

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**ABSTRACT**

This review gives key information about seed systems with the objective of helping countries in sub-Saharan Africa (SSA) to design appropriate strategies based on their own local realities. It starts with an in-depth assessment of the rice seed sector and emphasizes the factors that can influence its development. These factors may be associated with the biological characteristics of the rice crop, the complexity of farming systems, the policy environment, and the markets. The historical background of the seed sector in SSA is described in order to give a clear picture of the different attempts to find solutions in different countries and sub-regions. Five major strategic models and several alternative seed strategies are identified. However, local traditional seed systems will remain the primary source of seed supply for the majority of farmers for many years to come. These systems are based on farmer-saved seed and farmer-to-farmer seed exchanges, which are efficient tools in seed dissemination and food security. It is time to recognize local traditional systems and their contribution to the maintenance of seed quality and crop diversity and to develop tools for their better utilization. The community-based seed system (CBSS) is proposed as such a tool. CBSS encourages technicians to recognize local traditional seed systems and to build integrated seed approaches that take into consideration local realities and the socio-cultural dimension of seed within African communities. This will likely require a transition period of 5 to 10 years to build the fundamentals of sustainable seed systems through the structuring of the seed sector and the creation of appropriate conditions to ensure food security, enriched biodiversity and sustainable production. With climate change, local traditional seed systems, as well as integrated seed approaches, will likely play a more important role to improve the performance of agricultural systems while ensuring farmer autonomy.

**Keywords:** Conventional seed system, local traditional seed systems, integrated seed systems, community-based seed system, seed industry.

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## INTRODUCTION

African agricultural productivity is generally low, especially among poor smallholder farmers. A range of factors explains this low productivity, including the infrequent availability of improved varieties that are well adapted to low input systems and the absence of appropriate policies to encourage the development of the seed sector and ensure the sustainability of farming systems. Indeed, national seed systems are unable to meet farmers' needs for quality seed of improved varieties for intensive agricultural systems.

Most farmers regularly resort to using traditional local varieties and associated knowledge in seed production through farmer-saved seed, seed conservation, and seed diffusion. Usually, these varieties are not officially recognized. They are, however, efficient in maintaining diversity within the rice crop as a source of sustainability and adaptation to climate change.

Röling and Wagemakers (1998) suggest that it is important to look at agriculture as one of the oldest ways in which humans modify ecosystems to produce the goods and services they desire. For them, agriculture plays a leading role in issues of land degradation, habitat

loss, ecosystem loss, water scarcity, pollution, energy, and climate modification. Developing more sustainable agro-ecosystems will likely require seed systems that involve strong links between agriculture, ecology and society.

The issue of appropriate seed systems has been raised many times during recent decades and came to the forefront specifically in 2008 when food prices soared and seeds of food crops were not available. Most Western and Central African countries tried without success to import seeds from East Africa, mainly from Uganda. Others initiated relief programs with assistance from donors and technical partners (including the United Nations Food and Agriculture Organization (FAO), African Development Bank, World Bank, West African Development Bank, Japan International Cooperation Agency, International Fund for Agricultural Development, and European Union. These actions are worthy but not enough to efficiently face farmers' needs in the long term.

Interventions by the private sector are erratic and limited to hybrids and high added value crops (cash crops and vegetables). Cereals are, in general, covered by private companies only when government subsidies are available.

It is, however, important to remember that seed is the first input in agriculture. Guaranteeing farmers' access to quality seed can only be achieved if there are viable seed supply systems to multiply and distribute the seeds that have been produced or preserved and if mechanisms to assist farmers in emergency situations have been established. To that end, agricultural policies must emphasize seed strategies that can ensure the availability of locally appropriate varieties to men and women farmers in a timely and affordable fashion.

Rice is used as an example in this paper, as it is a food crop which is mainly cultivated in subsistence agriculture and, at the same time, as a cash crop. This means that different seed systems – both local traditional and conventional – are used. To better address the issue, it seems necessary firstly to give a clear picture of rice-farming systems, secondly to call attention to positive impacts but also limits of conventional and traditional local seed systems, and thirdly, to raise questions related to integrated seed strategies and decentralized approaches.

## EVOLUTION OF THE SEED SECTOR IN SUB-SAHARAN AFRICAN COUNTRIES

### Brief historical background

The evolution of the seed sector is in general tightly linked with the evolution of research and development approaches in Africa. Three major periods can be identified: (i) Before independence to the 1980s – the provision of seeds was state-managed; (ii) 1980 to 1990s – the seed sector was liberalized and privatized; (iii) 1990 to 2013 – the role of farmers' groups is increasing.

#### *Period I*

During the first years of independence, African countries focused on the development of the state farm sector, communal villages and cooperatives. The period was characterized by the leadership of state-managed companies, which controlled the whole seed value chain – from seed production to seed commercialization and seed distribution. This system applied to most cash crops, including cotton, groundnut, and vegetables. Seed was sold to farmers' cooperatives by private companies such as SOFACO, Callivoire, and Semivoire in Côte d'Ivoire, Pioneer in Nigeria, and CFDT[1] in Senegal. These companies were supported by research institutes in Belgium, England, France, USA and elsewhere.

Governments gave strong support for the development of the seed industry in many countries in Western and Southern Africa through the creation of seed stations, conditioning units, and storage facilities. National seed rules and regulations were elaborated with the objective of helping to develop seed markets. Seed laboratories were also created. Seed inspectors and technicians were trained with assistance from FAO and foreign countries (e.g. Belgium, France, Germany, the Netherlands, and the USA). Strategic seed security stocks were established in many countries in case catastrophes occur (e.g. rice in Nigeria, soybeans in Côte d'Ivoire, groundnut in Senegal, and maize in Zimbabwe).

Regarding cereals, only irrigated rice and maize benefitted from state support, while rainfed crops, owned by the family farm sector, were more or less neglected and populations suffered greatly from seed shortages during the droughts of 1968 and 1974.

#### *Period II*

This period corresponds with the liberalization/privatization of the seed sector. The process started at the end of the 1980s. The equipment that had been acquired by the states was sold and state-managed companies privatized. Private seed companies were encouraged to become established and to take positions of leadership (Cromwell, 1996). However, the process did not survive long and most seed companies collapsed. Markets were small because they were limited to irrigated zones within national boundaries.

Moreover, the process of liberalization/privatization of the seed sector has also had a negative impact on the evolution of the national seed services and national seed policies. Consequently, in all countries national seed

[1] Compagnie Française pour le Développement des fibres Textiles

programs collapsed gradually.

### *Period III*

During this period, more responsibility was given to farmers and the private sector. Many seed farmers' groups and professional unions such as "interprofessions" (rice inter-branch organizations) were created. Local private seed companies emerged but many collapsed at an early stage of development because of narrow markets and lack of information on seed demands from farmers. With the exception of a few countries (such as South Africa where the commercialization of hybrid maize and vegetables is well organized), there is very little evidence of successful commercial seed sector development. However, since the 2008 food crisis, the situation has improved greatly. Several farmers' groups were able to access subsidized credit for seed in most western, eastern, and southern African countries. In particular, in countries of West Africa (e.g. Benin, Burkina Faso, Côte d'Ivoire, Mali and Senegal), this opportunity was extended to long-term investments for tractors (and accessories) and seed-processing machines. Harmonized seed rules and regulations were adopted in Regional Economic Communities. This environment has led to the development of many small-scale private companies and rural seed enterprises.

## Main factors influencing the development of the rice seed sector

Many factors have been identified as having key influences on the development of the rice seed sector. Among them the following factors were recorded as playing a key role in the development of the seed sector: (i) specificity of the biology of the rice crop; (ii) complexity of production/farming systems; and (iii) policy environment.

### *Biology of the rice crop*

The structure of floral organs and the brief period of receptivity of the pollen grains have allowed rice to become an autogamous and self-pollinating crop. Rice flowers are generally self-pollinated because of a number of limiting factors (length of style and anthers, structure of the stigma, limited pollen viability, brief period of opening of florets, and release of pollens (between 30 s and 9 min) (Morishima, 1984; Oka and Morishima, 1967; Oka, 1988). This characteristic is important as it favors the conservation of rice seeds with unvaried characteristics for several years because of the very limited rate of outcrossing. This can occur but does not usually exceed 0.05% for cultivated rice species (Oka, 1988). It has been reported that the outcrossing rate of wild species is higher. In the case of red rice biotypes, depending on the humidity level and the temperature, the outcrosses can be as high as 0.2% (Shivrain et al., 2009).

### *Predominance of farm-saved seed*

The actual upland and rainfed lowland rice seed systems in Africa consist of the management and use of own-saved seed and informal sharing in the good years when there are no problems, and sourcing seed from the local grain markets when there is a shortfall in farmers' own-saved seed. These are individual transactions where the farmer usually knows the seed seller and is able to verify the origin of the seed being considered for purchase. The Communities' Trust makes grants to support seed exchanges and seed commercialization in this situation, representing a form of seed certification.

## Complexity of production/farming systems

Rice is grown mainly in four major agro-ecological systems: upland, hydromorphic, lowland and irrigated. The farming systems differ from each other in terms of constraints and potentials. Rice species are usually adapted to grow in at least two ecosystems. In some exceptional cases they are suitable for all four ecosystems but differ in productivity (from 1 to 8–10 metric tonnes per hectare) and in quality (e.g. protein content, palatability, and presence of aroma).

Each crop variety may be adapted to a particular type of soil, climate and growing season. Its genes may endow it with traits needed by farmers: disease resistance, cold or heat tolerance, special taste or nutritional qualities, etc. These qualities provide farmers and plant breeders with raw materials to improve their crops and adapt them to the changing environmental conditions.

Concerning seed production, two major ecosystems can be distinguished: irrigated and rainfed zones.

Although Africa has large water resources with irrigation potential for 90 million hectares, crop land that is currently irrigated represent less than 10% of the existing potential, that is, much less than in India (26%), the Philippines (40%) and China (44%). Most of the irrigation schemes are located within the major drainage basins (e.g. Congo, Nile, Niger, Orange, Senegal and Zambezi) and lakes (e.g. Chad, Victoria, and Tanganyika). They represent only 3% of all cultivated areas in SSA (FAO, 2006a). As shown in Figure 1, each agroecological ecosystem is subject to its own particular constraints.

Under irrigation, seed production is conducted under intensive conditions using in many cases the

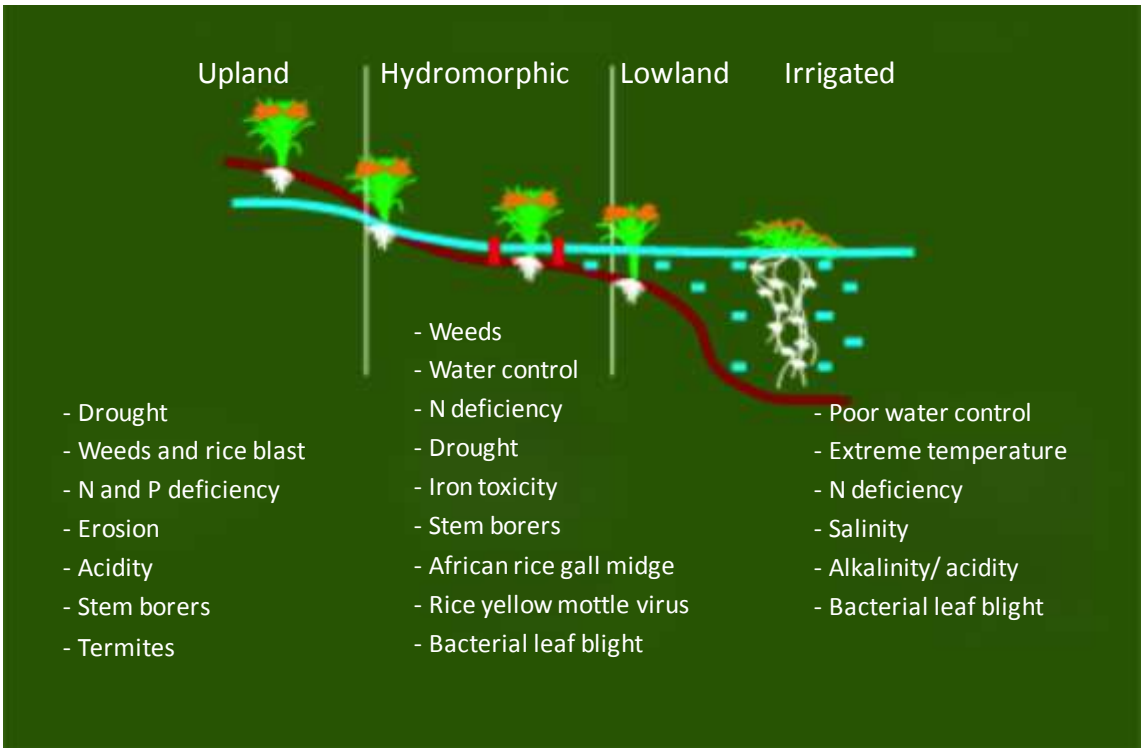


**Figure 1.** Major constraints by ecosystem.

**Figure 2.** Crop diversity and diversity within crops.

conventional seed system. Irrigated zones are known for utilizing improved varieties because of their high value returns. Credit is available for farm inputs such as fertilizers and seeds.

In the rainfed ecosystems, which cover roughly upland, hydromorphic, and lowland areas, farmer-saved seed is common. The environment is characterized by small and dispersed farmers' plots. Resource management practices are often complex and interdependent.

In these systems, diversity is the norm and farmers cultivate a great number of rice varieties (up to 10 in some households in forest zones) in association with tubers and roots, maize, and legumes (Figure 2). By mixing crops, farmers reduce risk in case natural catastrophes occur (such as drought and flooding), reduce crop losses from pests and diseases, and make more efficient use of farm labor (Dixon et al., 2001).

## Policy environment

The policy environment relates to the existence of seed legislation, variety registration, the functioning of the national release committees and national seed services with real capacities to conduct seed certification, and access to credit and markets.

Until recently, most African countries did not have a conducive policy environment. Agricultural policies

adopted in the first years of independence favored collective farming and state farms. In countries like Côte d'Ivoire, for example, big state seed stations were opened in Touba and Odienne under the 'Office des semences et plants'. In Touba, storage facilities were installed to store up to 3,200 tonnes of seed of soybeans and 1,600 tonnes of rice seed. A seed-testing laboratory (Laboratoire national des semences et plants) was created in Yamoussoukro with the objective of giving support to private seed companies. Indeed, all investments in the agricultural services were geared towards the development of the commercial farming sector.

However, it should be mentioned that in general, seed testing, wherever it exists, is centralized and suffers budgetary constraints. Farmers are asked to pay for field inspections and laboratory controls and for technicians to travel to conduct field visits. Those who do not pay cannot benefit from seed controllers and their seed is not certified. Therefore, policy measures and guidelines emanating from governments concerning the seed sector do not address the real needs and problems of the small-scale or subsistence farmers.

In the last two decades, FAO, in collaboration with the Consultative Group of International Agricultural Research (CGIAR) centers, sub-regional organizations (Southern African Development Community [SADC], Association for Strengthening Agricultural Research in Eastern and Central Africa, and West and Central African Council for Agricultural Research and Development), and European, American, and Japanese governments assisted most countries in Western, Central, Eastern, and Southern Africa to elaborate national legislation and to train national inspectors and laboratory controllers. In addition, harmonized regulatory frameworks and regional varietal catalogs were developed at regional levels (the examples of West African Economic and Monetary Union (WAEMU), Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel and Economic Community of West African States (ECOWAS). That means private companies can now evolve beyond national political frontiers. Henceforth, at least in theory, once a variety is released in a country, it is possible to sell its seeds in all the countries belonging to the same agro-ecological zones within the same sub-region.

Indeed, the harmonized seed rules and regulations are still difficult to implement on the ground despite state approvals. Firstly, statutory seed standards adopted by the sub-regions seem to be high because they are extracted, without any deep adaptation, from existing seed standards derived directly from European standards. Consequently, they are relatively difficult to achieve by most small seed producers. Secondly, national seed boards and seed control infrastructures are still not operational in most countries. Thirdly, seed regulations are never a finished business. Alongside technologies, seed legislations need to be adapted. Seed regulations targeting simple varieties are not the same as those covering hybrids or genetically modified organisms.

## SOME KEY PARTICULARITIES OF THE SEED INDUSTRY IN SUB-SAHARAN AFRICAN COUNTRIES

In both Africa and Asia, rice is considered as a cash crop only in irrigated zones where it benefits from subsidies for seed and fertilizers, which are incorporated in the conditions for gaining access to credit. In rainfed zones, the situation is different. However, some successful experiences were recorded, mainly with maize (in Malawi and Zimbabwe), after the severe drought in the 1991/92 growing season, in the form of a "Starter Pack scheme" followed by the distribution of hybrid seed and fertilizer in subsequent seasons. The same good results were registered with maize in cotton-growing zones in Western and Central Africa.

### Specificities of the seed industry in Western and Central Africa

The development of the seed industry is weak in Western and Central Africa. Few private companies exist and they mainly focus on the production of maize and sorghum hybrids. Rice seed production is usually not attractive for the private sector due to its self-pollinated character. The value-added margin is very small. Once farmers get access to new varieties, they tend to use the seeds obtained for many years before renewing them.

Despite this, it is important to mention that there are significant opportunities for the development of the seed sector. Seed is seen in all countries as the first input in agriculture. Farmers are constantly looking for new varieties. Especially with climate change, they look for varieties that are early maturing, tolerant of drought, iron toxicity, and acidity, or that are well adapted to flooding, bird damage or insect attacks.

### Specificities of the seed industry in Eastern and Southern Africa

In these regions, the seed industry is well developed for most crops (maize, wheat, sunflower, and pulses) except for rice, which is dominated by the traditional local seed sector. However, some specificities can be underlined. In Tanzania and Zambia, for example, Quality Declared Seed (QDS) is widely used.

In Tanzania, quality control is done on-farm by farmers, while the official seed certification authority performs spot-checking of the seed and occasional field supervision. The Tanzania Official Seed Certification Agency inspects only 10% of the crop.

The QDS, developed by FAO, looks for less rigid seed

legislations for countries that are not able to meet the International Seed Trade Association standards. According to Britt Granqvist, Denmark (2009), QDS is designed to assist the growth of the seed trade while encouraging the use of quality certified seeds.

Truthfully labeled seed is also used. It is uncertified seed that meets minimum prescribed laboratory standards regarding the genetic purity, germination rate, and moisture content laid down for a variety. Through this, companies are allowed to do their own tests but are not authorized to carry official certification tags.

### Successful experiences of the seed industry in Asia

In Asia, the seed industry benefited greatly from the effects of the Green Revolution in the 1960s to 1970s when parastatal agencies provided an institutional framework within which private companies could develop several seed activities including breeding, multiplication, processing, marketing, certification, and commercialization of seed of high yielding varieties.

In particular, in South Asia (India, Pakistan and Bangladesh), private companies also benefited from seed processing units which were established with assistance from World Bank projects.

Regarding policy issues, the optional seed laws on seed certification, together with the large market size, have helped India to develop a seed industry rapidly.

In general, seed of self-pollinated crops like rice is subsidized both for private and public companies per kilogram of seed sold. Through this system, private companies are encouraged to provide farmers with rice seed. However, private companies target mainly hybrids while self-pollinated seed is under the responsibility of public companies.

Private companies are encouraged to work at the level of provinces through incentives. Despite that, the replacement rate of self-pollinated seed per year is still low – around 5% against 100% for hybrids (SeedNet India, 2002). Focus is then put on providing advice on production techniques such as seed sorting, germination rate testing, rouguing, on-time harvesting, and proper storage. Private companies are also authorized to provide seed processing and treatment services to farmers.

## MAJOR SEED SYSTEMS IMPLEMENTED IN SSA COUNTRIES

Generally, three major seed systems and delivery models are registered in SSA countries:

(i) The conventional seed system
(ii) The traditional local seed systems
(iii) The integrated seed system.

### Conventional seed system

The conventional seed system includes both the public, or government, and private or commercial, seed sectors.

Once a national release committee releases a variety, authorization to produce improved seed is given. At the beginning, just a few panicles (around 100) are planted to constitute Breeder seed (G0) from which Foundation seed (G1, G2 and G3), Registered seed (G4) and Commercial seeds (R1 and R2) are produced (Figure 3).

The conventional seed system (also called the formal seed system) is intended to provide certified seed. The system is market-oriented and has uniform standards based on distinctness, uniformity and stability. The system is influenced by a large number of policies in research, variety release procedures, seed production, and trade rules and regulations with the objective on the one hand of protecting countries against the introduction of foreign pests (insects, diseases and weeds) and on the other hand, of organizing the functioning of the seed system at different stages, (e.g. identification of seed growers and their competences, field inspections and laboratory analyses, supervision of seed conditioning, regular visits to commercialization points). If a farmer is unhappy with the quality of the seed bought, cross-check analyses are conducted by national and, in some cases, international accredited seed laboratories and the bad seed batches are seized. Other administrative measures including legal actions can also be taken.

### *Conventional seed system and genetic diversity losses*

The conventional seed system seems to be designed mainly for cash crops. Others crops particular to small-scale farming systems get little attention. They benefit from farmer-saved seed through farmer-to-farmer seed exchanges.

The systematic promotion of uniform improved varieties has led to decreased genetic diversity, both within and between varieties and species. According to Hoisington et al. (1999), this is mostly due to the widespread replacement of genetically diverse traditional varieties or landraces by homogeneous modern varieties.

It has been suggested that the resulting crop genetic homogenization is a threat to the sustainability of production systems, and several studies now emphasize the importance of both inter-specific (Altieri, 1999, 2001; Lin, 2011) and intra-specific crop diversity (Macfadyen and Bohan, 2010).

In spite of an increasing number of registered crop varieties since the 1960s, the majority of agricultural land in developed countries is now covered with a few “winning” productive varieties, with generally a single crop per field, so that the actual cultivated diversity is low (for examples from France, see FranceAgriMer and

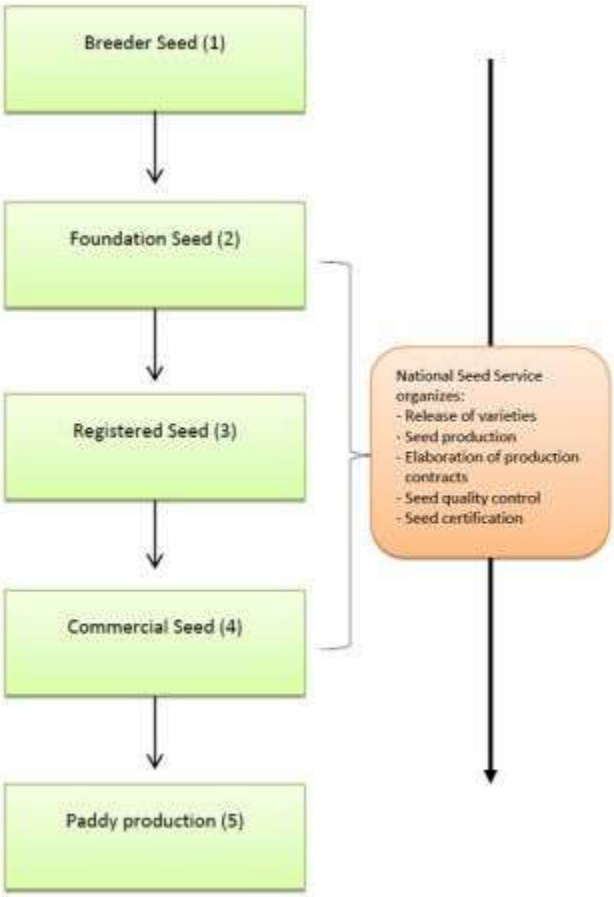


**Figure 3.** Major stages of the conventional seed system. The system is centralized and regulated by the MoA through the NSS.

ARVALIS Institut du Végétal, 2009).

The uniformity of species and varieties represents a loss of genetic diversity, including the loss of individual genes and particular combinations of genes. This may have dangerous effects on the farming systems by increasing susceptibility to particular pests, pathogens or environmental constraints. Notable examples described in the "State of the World's of the Plant Genetic Resources for Food and Agriculture" (FAO, 1997) include:

(i) The potato famine in 1845 to 1848 when a pandemic of late blight (*Phytopthera infestans*) wiped out the potato crop in Europe and North America;
(ii) The epidemics of shoot fly (*Atherigona* spp.) and Kamal bunt (*Tilletia indica*) in the 1970s;
(iii) The destruction of more than 15% of the US corn crop by a new race of corn leaf blight in 1970;
(iv) The winter wheat cultivar "Bezostaya" was wiped out from Ukraine in 1972 by a severe winter;
(v) In Cuba during 1979/1980, a rust attack of a variety of sugar cane resulted in the loss of more than 1 million tonnes of sugar.

In Africa, several cases were recorded. Among them, one can cite:

(i) The rapid evolution of the Cassava Bacterial Blight (*Xanthomona saxonopodis* pv. *Manihotis*) and the mealy bug (*Phenacoccus manihoti*) or the *Cercospora* of banana in the 1980s;
(ii) The destruction by the groundnut rosette virus of part of the Bambey groundnut collection of seeds, in 1952;
(iii) The destruction in Northern Nigeria by the groundnut rosette virus of 0.75 million hectares of groundnut that were cultivated under the variety 55 to 437 (Yayock et al., 1976).

### *Plant breeding and biodiversity*

It is now accepted in the developed countries that crop genetic diversity has been decreasing steadily in the agricultural landscapes since the early 20th century (FAO, 1997; Secretariat of the Convention on Biological Diversity, 2006).

The decrease of crop genetic diversity (also called genetic erosion) has also had a very negative impact on the existence of wild species and landraces that represent very important sources for food security but also, for plant breeding. These materials are frequently used in plant breeding with the objective of developing specific breeding programs for micronutrient-content improvement including wild species (Louwaars et al., 2003).

Nowadays, many crosses are being made to enrich the genetic diversity of species. For example, at the Africa Rice Center (AfricaRice), many crosses were made between *Oryza sativa* and *O. glaberrima* (cultivated crops) with wild species like *O. longistaminata*, *O. barthii* and *O. stapfii*. These species offer many advantages in terms of adaptation to climate change and to different ecologies of upland, lowland, irrigated mangrove zones and deep water. They offer also made available to the target populations in order to improve their nutritional status and health, to children suffering from avitaminosis, and to diseased populations suffering from diabetics and high blood pressure.

### Evolution of the seed systems since the 1980s

Since the structural adjustments that occurred in the 1980s in the developing countries, the inefficiency and ineffectiveness of public seed supply systems was recognized (Cromwell and Wiggins, 1995).

In Senegal, for example, less than 80% of the seeds used by farmers in the 1970s were farmer-saved seed (Venkatesan, 1994); but this has increased drastically after the structural adjustments.

From that period, many national development structures and seed services have been significantly

reduced while the involvement of private companies has not been effective. Several companies tried to take over the vacant places left by national development structures but had to give up quickly. The market was narrow and not well structured. Recently, in the last two decades, alternative seed strategies for smallholder seed supply have been developed in several countries (Rohrbach, 1997; FAO, 2006b). An example is the QDS in Tanzania and Zambia.

Other seed classes are used in some countries in Eastern Africa: Guaranteed Seed in Mozambique, Standard Seed in Botswana, Commercial Seed in Kenya and Uganda, and Approved Seed in Malawi. In West Africa, precisely in Senegal, private Authorized Technicians are accredited to conduct field inspections instead of State Inspectors.

Alternative strategies to the conventional system are used in many SSA countries with the objective of improving farmers' access to improved varieties. They differ from one country to another but they all tend to transfer more responsibility to farmers. This is really interesting because farmers look all the time for different types of genetic materials including landraces, breeding lines and neglected species. In addition, farmers are the only ones who know what their own needs are.

## Traditional local seed systems

Traditional local seed systems are filling the large gap created by the poor performance of the public sector and the low interest from the private sector (Ntare, 2001; FAO/TCIW, 2002; TripleLine, 2008). These are mainly traditional, informal systems operating at the community level through seed exchange mechanisms. Farmer-saved seed is the most common way to obtain seed. Farmers also use other diverse seed supply sources. They get seed from friends, relatives, extension agencies, and research. They also from time to time purchase seeds from the local markets (Haugen, 2001).

These systems offer a range of landraces, local cultivars and improved varieties that are accessible and are of acceptable quality. The systems are often described as operating at the local level. Therefore, they offer cheaper and more efficient ways of delivering seed to farmers especially at low or no transaction costs.

Traditional local seed systems are also wonderful sources for the development and the maintenance of the diversity of crops within and between species and their wild relatives (Almekinders and Louwaars 1999; Jarvis et al., 2000). According to Cary Fowler (2008), "diversity is one of the most fundamentally important resources for human life. This diversity is awe-inspiring. It provides the natural, biological basis of our ability to grow the food required today, as well as to meet the challenges of population growth, changing climates and constantly evolving pests and diseases."

The diversity of varieties is high. It comprises local traditional varieties, landraces, improved varieties, and breeding lines. This is mainly typical for rainfed upland rice cultivation. According to Haugerud and Collinson (1990), it is recognized that farmers select cultivars on criteria that go beyond the yield potential envisioned in conventional plant breeding schemes. Cultivars of different maturities are often required to accommodate early or late planting, variability in rainfall, or compatibility with intercrops or rotations; storage characteristics often assume greater importance for the farm household than for the plant breeder; local food preparation techniques and preferences often favor one cultivar over another; utilization of non-grain biomass (e.g. leaves, stalks) for fodder, fuel, or building and other uses. These factors are not ethnographic curiosities but rather form part of the rigorous selection criteria that farmers use in accepting, or rejecting seed of a new cultivar.

As usual, in SSA, the diversity of the varieties is maintained by some families who are given the responsibility to take care of them on behalf of the communities (for example, ruling families in any traditional community). Whatever happens, the local communities have to respond altogether. In fact, seeds are vehicles of the civilization and the traditions and have to be made available to all members of the communities.

In Casamance (south Senegal) for example, in the *Diola* ethnic group, the King has the duty to conserve all existing varieties for several generations, including varieties with special taste, nutritional values or important socio-cultural values linked with religious and cultural ceremonies (e.g. spreading of seeds of some selected varieties during marriage ceremonies as sign of fecundity, feeding of circumcised young boys with red[2] and black[3] rice). The King has also to ensure that everybody is able to plant the needed variety at the appropriate planting time.

Although National Seed Strategies refer to the local traditional seed systems, the National Agricultural Policy Documents do not make reference to them. In countries like Senegal, these are called 'Reserves personnelles'. Seed legislations do not recognize them and do not provide a way for them to be formalized. Consequently, local traditional seed systems are known as the 'informal seed sector', which means "non official", or "out of law". However, local varieties sell well in local markets or through seed fairs and voucher systems (e.g. in Burkina Faso, Mali, Mozambique, Rwanda).

Traditional local seed systems are not market-oriented and consequently do not use the same norms as

[2]Red rice has a nutty flavor, and a high nutritional value, as the germ of the rice is left intact.

[3]Black rice contains vitamin E, which bolsters the immune system, B vitamins and minerals (potassium and iron). B vitamins are an extremely important component of overall health; they increase the rate of metabolism, maintain healthy skin and muscle tone, and enhance immune and nervous system function.

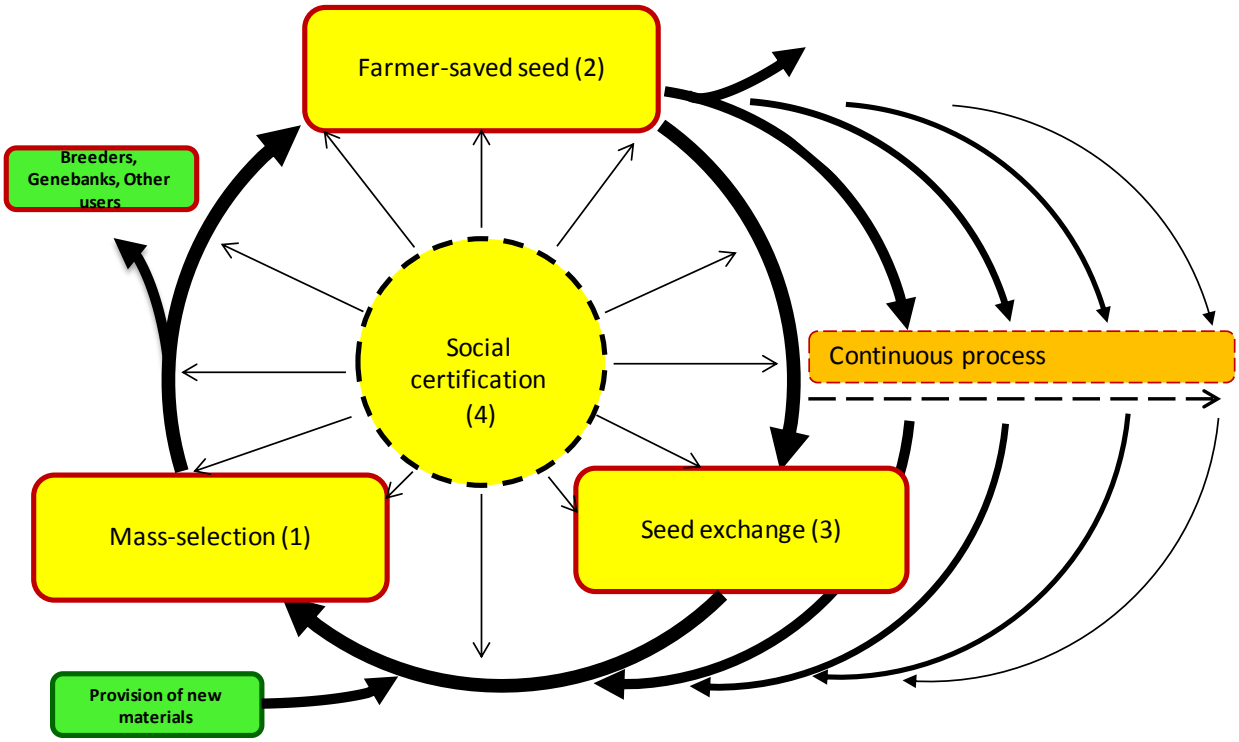


**Figure 4.** Traditional local seed systems. Adaptation (Bèye and Bâ, 1998).

conventional seed systems. Seed certification is here done by whole communities who rely on field observations and on trust. This is called 'social certification'. In reality, once a farmer has been deceived by the quality of the product given by a provider, all other farmers will boycott the provider forever.

Farmers operate mass-selection, which is conducted each cropping season. Sometimes, varieties are developed through selection of new characteristics that appear spontaneously in the populations. This process of renewal is associated with "informal" seed exchanges, "local" or "traditional" social structures and systems of knowledge, which can in fact be very modern (in agro-ecological terms, for instance).

Farmers' varieties are selected and produced most often for the producer's own consumption; the quality of farmer varieties obeys superior standards. This is typically true regarding nutritional values and taste. According to "Seeds and Farmers' Rights" (2011), this is not the case for commercial varieties, selected principally for their returns and adaptation to industrial production methods, mechanization, transport, longevity on supermarket shelves, and other characteristics.

That means that selection is a continuing process with a dynamic interaction between nature (agro-biodiversity) and farmers' careful selection and breeding. Figure 4 shows how traditional local seed systems function. Once a farmer gets a variety, he will usually first check its purity and germination rate. Then, he will plant it and at harvest time collect the best seeds to be stored for the next season. If the seed comes from outside (mainly from the market), the farmer will ask for advice from his friends and relatives, and sometimes from the local extension technician. Here, trust will be decisive. Figure 4 also shows that 'social certification' is done at any time and at all stages (growing plant, seed).

The system operates seasonally through four major activities: mass-selection, farmer-saved seed, seed exchange, and social seed certification. It benefits also from a regular provision of diverse genetic materials coming from outside (e.g. landraces, local and improved varieties, breeding lines).

Another particularity of local traditional seed systems is that usually there is no clear difference between the consumed grain and the stored seeds. For the farmer, they are both important. In addition, the seed is of variable quality (of different purity, and physical and physiological quality) (Almekinders and Louwaars, 1999). The steps in seed choice, multiplication, dissemination, and storage take place as integral parts of farmers' production systems and are guided by local technical knowledge and standards and by local social structures and norms (Sperling and Cooper, 2003). This way of acting prevents huge losses of seeds. However, traditional local seed systems are exposed to external catastrophes like natural disasters (drought, floods or pest outbreaks) and civil wars. Seed movements are intensive within the local communities and even beyond.

### *Farmer-saved seed and official legislation*

While saving seed and even exchanging seed with other farmers for biodiversity purposes has been a traditional practice, these practices have become illegal for the plant varieties that are patented or otherwise owned by some entity (often a corporation). Under Article 28 of the Agreement on Trade-Related Aspects of Intellectual Property Rights (the TRIPS Agreement), "planting, harvesting, saving, re-planting, and exchanging seeds of patented plants, or of plants containing patented cells and genes, constitutes use" and is prohibited by the intellectual property laws of signatory states (Vellve, 1992).

Significantly, farmers in developing countries are particularly affected by prohibitions on seed saving. There are some protections for re-use, called "farmer's privilege", in the 1991 International Union for the Protection of New Varieties of Plants (UPOV Convention), but seed exchange remains prohibited. In contrast, in the USA the farmer's privilege is considered protected by the Plant Variety Protection Act and by case law stemming from Asgrow Seed v. Winterboer. American farmers may sell seed up to the amount saved for replanting their own acreage (The Crucible II Group, 2001).

### *Evolution of official seed regulations and farmers' rights*

Farmers are good plant breeders. They constantly target the preservation and the maintenance of the diversity of species and varieties. They look for healthy and sustainable food systems for the benefit of their local communities, their economies, and environments. These concepts are different than those developed by the multinational companies which look for more profit through the monopoly of few varieties.

According to Diamond v. Chakrabarty, companies may obtain patents for life forms while J.E.M. Ag Supply v. Pioneer, consider that seed saving is a patent violation (Mechlem and Raney, 2007). That situation has now evolved and farmers' rights are taken into account more and more.

At the FAO Conference in 1989, member countries endorsed the concept of Farmers' Rights which was defined as "Rights arising from the past, present, and future contributions of farmers in conserving, improving, and making available plant genetic resources particularly those in the centers of origin / diversity". From that point, several developing countries defended farmers' rights as rights to: (i) Protect traditional knowledge; (ii) Share in the benefits of the use of genetic resources; and (iii) Participate in policy making relevant to genetic resources.

Two interesting cases can be cited:

1. In India: Farmers have the right to save, use, exchange, and sell farm-saved seed, but not on the commercial market.
2. In Ethiopia: Smallholder farmers have the right to save, use, exchange, and sell seed without restrictions. Commercial farmers may be allowed to save seed for food crops for national food security while export-oriented enterprises (horticulture) have to follow the international standard (no saving of seed).

According to Louwaars (2012), in his communication towards the Plantum members, "Stimulating innovation in plant breeding", courts in Europe and the USA are becoming more critical regarding patenting issues. He gave the following examples:

(i) The Dutch government is preparing a law for a limited breeder's exemption;
(ii) The German Parliament is calling for a stop on patenting of conventionally bred plants and animals (January 2012);
(iii) The Dutch Parliament reiterated the need for a full exemption and calls for an amendment of the EU Biotechnology Directive (February 2012).

These changes raise the hope that farmers' rights will be better preserved and farmer-saved seed recognized by researchers. Integrated seed systems conceal interests of both seed systems: conventional and traditional local systems.

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGR) adopted in 2001 offers opportunities for greater respect for farmers' rights by establishing an efficient and effective way of facilitating access to plant genetic resources while sharing the benefits from such a system in a fair and equitable way.

### Integrated seed systems

The conventional seed system is known to be typically characterized by heavy and inefficient bureaucratic structures with classic seed regulatory frameworks and inadequate access to markets (Lipton and Longhurst, 1989; Tripp, 2001; De Boef et al., 1997).

As mentioned earlier, the conventional system is market-oriented. That means the marketing component takes the lead in the chain. But in reality, this has not happened in SSA countries. The focus was put mainly on development aspects privileging breeding and seed production activities excluding commercialization for which the system is designed. That shift from market-oriented to development-oriented chains derives from the importance given by the private sector mainly to high value crops (cash crops and hybrids).

In contrast, traditional local seed systems are more development- than market-oriented. Smallholder farmers operate in complex, risk-prone, and diverse environments. In such environments, it is difficult to use

only one seed system. A diversity of approaches will be more consistent. However, the methodologies for seed regulation frequently constitute barriers for potential interactions between the conventional and the local traditional systems, other than those at the stage of germplasm collection and the commercialization of varieties (Tripp, 1997a, 1997b; Louwaars, 1994a).

In order to find appropriate solutions, several alternative schemes involving smallholder farmers were used by governments as well as non-government organizations (NGOs) in the 1990s (cases of Mozambique, The Gambia, and Zambia; Cromwell et al., 1992; Wiggins, 1992). Within those schemes, emphasis was usually put on seed production through contracts, supervision of the seed production, seed certification and seed processing. However, these schemes worked in parallel with local seed systems. They were also quickly captured by businessmen farmers, while stallholder farmers continued as usual to use farm-saved seed of both local and modern varieties.

A new concept called Integrated Seed System Development (ISSD) was designed to support the development of programs and policies coherent with the local realities of farmers. The objective was to create a useful conceptual framework for developing coherence among seed practices, programs, and policies. The system is intended to integrate both the conventional seed system and local traditional seed systems at the technical and institutional levels (Louwaars, 1994b; De Boef et al., 1997).

According to Louwaars and De Boef (2012), ISSD promotes two principles. The first principle leads to the facilitation of interactions between the conventional and traditional local seed systems by addressing the differentiation between development and market-oriented seed value chains in recognizing that no single public, private-, community- or NGO-based intervention can support seed sector development. The individual farmers themselves use different seed systems for different crops.

The second principle considers that the seed sector development needs to be approached in a pluralistic manner, including public, private, community-based, or NGO stakeholders, each of them assuming specific responsibilities in dissimilar seed value chains.

Through these approaches, ISSD has helped to better understand positive aspects as well as the limitations of conventional and local traditional seed systems. It accepts that all seed chains that play an important role in seed sector development, that is, instead of taking a linear approach (Douglas, 1980).

Like ISSD, another scheme called the Community-Based Seed System (CBSS) was developed in 1997 by Africa Rice and the Institut Sénégalais de Recherches Agricoles. The system derives from lessons learnt from different seed sectors including cotton and maize, and other food crops, *in-situ* management of plant genetic resources, and the socio-cultural dimension of the seed in African societies (Bèye and Bâ, 1998).

CBSS aims to perfectly integrate the strengths and opportunities in both the conventional (for the production of Breeder and Foundation seeds) and the traditional local seed systems (for diffusion techniques of improved as well as traditional varieties). The system aims to help farmers to better meet their seed needs, and to become linked to the market (Bèye et al., 2009). It also promotes food security agro-biodiversity and reveals the sociological, ethnographic, and environmental values of farmer-seeds. Figure 5 shows interactions between the two types of seed systems. These interactions go beyond simple seed exchanges and adopt a pluralistic approach that promotes complementary seed sector development including: (i) The regular provision of improved genetic material (Breeder and certified Foundation seed of improved varieties) and (ii) The provision of quality seed of local cultivars and landraces (when needed).

Figure 5 gives a clear picture of how the system functions at the community level and reveals four new functions of CBSS: adaptation of seed rules and regulations to local realities, enterprise development, decentralized quality control, and decentralized information gathering and diffusion. These four elements reflect the evolution of the system from its primary function targeting pure development-oriented prospects through awareness raising and training on production techniques to new functions targeting development – and market-oriented and food security purposes.

That shift has become compulsory when in 2004, as a result of the Africa Rice / Japan NERICA / CBSS-funded project; the farmer association COPROCOVIDA (Coopérative de Commercialisation des Produits Vivriers de Daloa) was unable to sell important stocks of seeds (600 tonnes of NERICA rice and 200 tonnes of maize of Acceptable Quality Seed). This situation has brought to mind that the implementation of the NERICA/CBSS project has boosted the productions of seeds, but has also created new problems for farmers who were not used to condition, store, and commercialize such large quantities of seeds. Moreover, the farmers had regularly to look for insecticides and to pay for missions of the national seed services (NSSs) whenever government-funded projects wanted to buy seed.

### *Adaptation of seed rules and regulations to local realities*

This is an important step towards the recognition of farmers' role in the supply of seeds, the *in-situ* conservation of the agro-biodiversity and crop genetic diversity, farmers' knowledge and farmers' rights. This will also bring plant breeders and farmers together to work more closely in variety development, variety evaluation, and variety release. As mentioned by

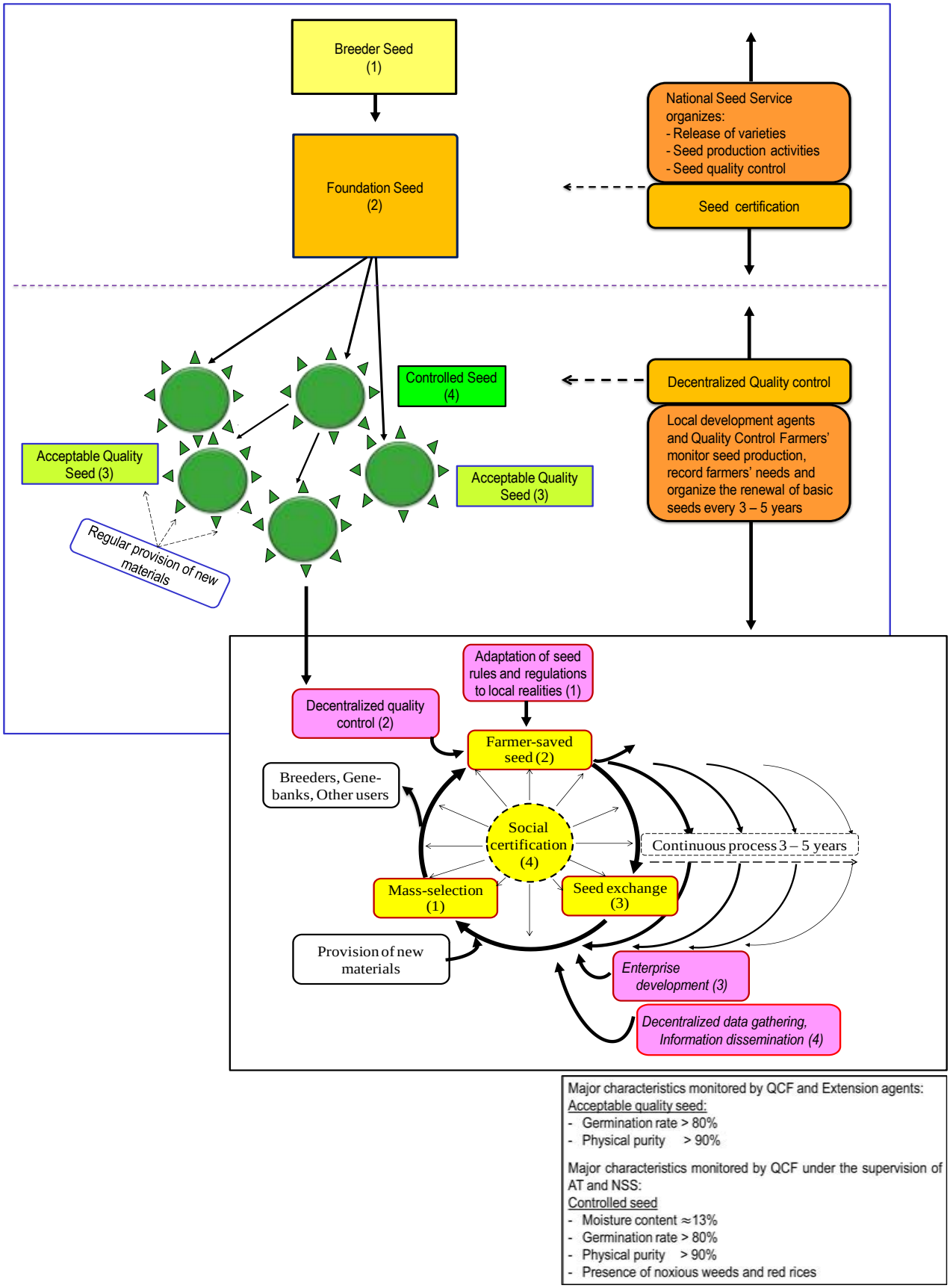


**Figure 5.** Integrated seed system (Case of CBSS); and detailed description of operations within the community.

Haugerud and Collinson (1990), apart from yield, farmers like grain quality, storability, suitability for intercropping, and the use and value of crop residues. These criteria may all influence their decisions about variety adoption. By adapting rules and regulations to local realities, policy makers will be helped to better consider the importance of the identification of farmers' needs, on-farm seed production and exchange, and the maintenance, development and registration of local varieties and landraces. Indeed, small-scale farmers perceive local varieties and landraces to be more adaptable to their agro-ecology, give stable yield, perform better under low soil fertility or low inputs, have good grain quality and are suitable for preparation of traditional foods (Bishaw, 2004).

The development of a policy framework which favors the recognition of local traditional seed systems alongside with the formal one will surely be beneficial for all stakeholders while targeting food security and sustainability of agricultural systems.

### *Enterprise development*

As related in "The CBSS Technician's Manual", Bèye et al. (2009) raised the question of specialization of individual farmers and farmers' associations in the production of quality seed. This will likely occur through: (i) The establishment of strong farmer groups which are capable of organizing seed production and seed commercialization activities including seed production planning, collecting and storing; (ii) The promotion of the quality seed of selected varieties for their specific characteristics; (iii) Working to increase resilience of farms, amongst other means by stimulating diversification of revenues and agro-biodiversity; and (iv) Connecting farmers to providers of inputs and credit.

Enterprise development is also meant to strengthen farmers' organizational capacities and to help them become "seed enterprises". Enterprises are expected to work in close collaboration with other stakeholders mainly public–private institutions on common social, economic, and environmental issues in a stimulating and enabling environment.

### *Decentralized quality control*

The concept of decentralized seed quality control is not new. It has been used with success in Western Africa, in Senegal and Côte d'Ivoire, and in Eastern and Southern Africa in Kenya, Uganda, Tanzania, Malawi, Zambia and Zimbabwe.

In Senegal for example, Authorized Technicians (ATs) assist Inspectors and Regional Seed Officers by monitoring most declared seed fields. These are private agents who are trained to conduct field inspections. For about 10 years, field inspections have been conducted in the Senegal River Valley by private agents for 60 USD per hectare per cropping season.

In this way, seed producers from UNIS (Union Nationale Interprofessionnelle des Semences) are able to produce annually around 2500 tonnes of certified seed which is enough to cover more than 50% of local seed needs in the irrigated zones of the River Senegal and Anambe. The remaining seed is sold in Mauritania, Guinea-Bissau, and The Gambia.

In the case of CBSS, the seed quality control is totally decentralized. It is run by individual farmers and farmers' groups who are trained to produce quality seed. These farmers and farmers' groups are monitored by Quality Control Farmers (QCFs) and ATs who are trained and accredited by the NSS (where it is functioning) or the Directions of agriculture. QCFs monitor the traceability of the seed and conduct seed quality controls for three parameters: physical purity, germination rate and moisture content. This work benefits from support from ATs and supervision at distance from the NSS. All the collected information, after verification by the leaders of the farmers' associations, is sent by smartphone to the central website: www.semence.org.

### *Decentralized data gathering and information dissemination*

CBSS enables smallholder farmers to meet their seed requirements by improving their know-how for addressing basic seed production practices and the quality maintenance constraints. Consequently, it provides a good opportunity for farmers' organizations to improve the supply of quality seeds in their communities and to gradually develop into viable seed enterprises. Market aspects are monitored and promoted through cyber-seed centers which at any time give information including details of available seed stocks and their characteristics (germination rate, moisture content, physical purity, and, in some cases, the presence of weed seeds), and the proposed prices and trends of productions by variety (Bèye, 2008).

A key element to improving agricultural production is the timely provision of accurate information in response to requests made by end-users of agricultural information (inputs, agricultural products).

A number of initiatives have come up to address this problem such as the provision of market information system, agricultural advisory services, rural radio, and village phones. These initiatives provide farmers with agricultural information but in most cases they are not easily accessible by farmers to meet their specific information needs. Especially for seed issues, they are not well adapted. Therefore, new tools were elaborated based on the work done by QCFs through a decentralized data gathering system called the "Cyber-

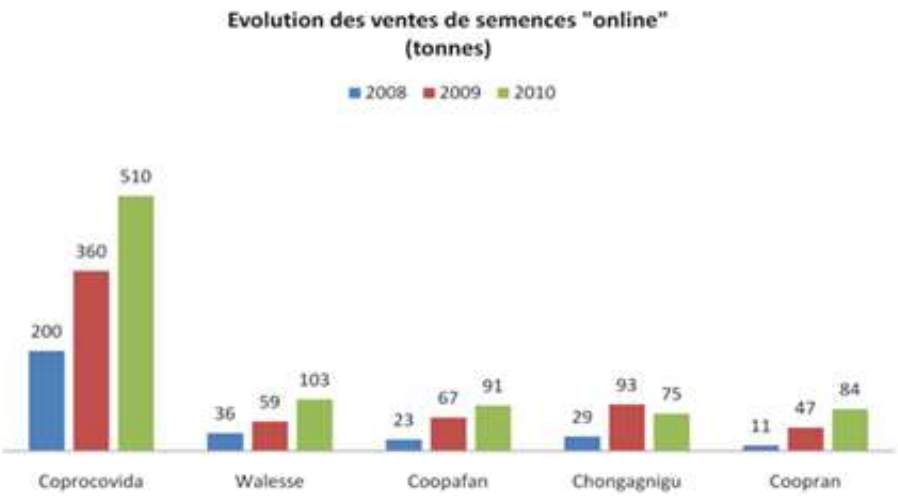


**Figure 6.** Estimations of online rice seed commercialization (Côte d'Ivoire, 2008 - 2010).
Sources : Compiled data from NERICA / CBSS Project Reports, PNR, ANADER.

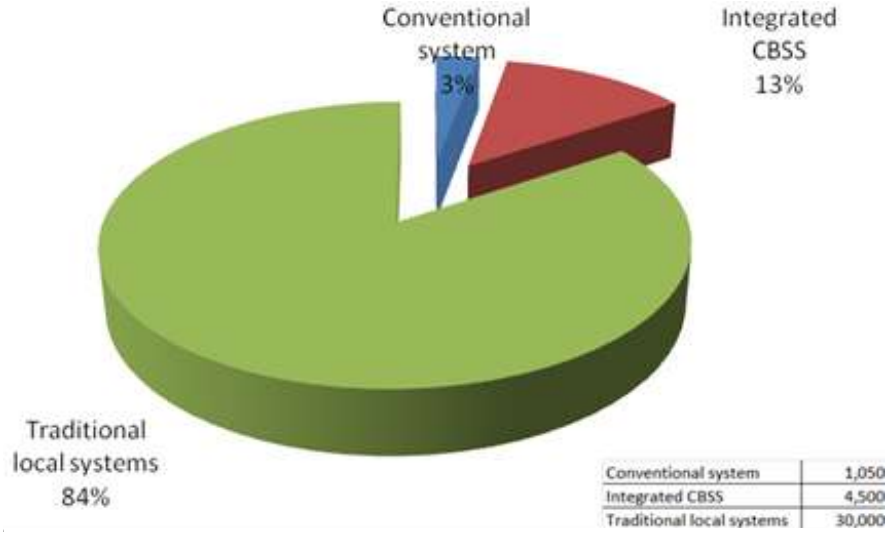


**Figure 7.** Estimations of productions of rice seed (Côte d'Ivoire, 2010).
Source : Compiled data from NERICA / CBSS Project Reports, PNR, ANADER.

seed network" (Figures 6 and 7).

The major challenge is in making the appropriate information broadly available to farmers through the multitude of national and NGO programs in a form whereby they can absorb the most relevant elements into their own practices. The creation of Internet access centers in a cyber-seed network can help farmers and seed suppliers to communicate with traders outside of their immediate surroundings (Bèye, 2008). This goes in parallel with available other existing marketing and information tools.

Nowadays, most farmers continue to manage and use a portfolio of varieties, often both local landraces and modern varieties.

Local landraces continue to play a crucial role in many farming systems for two major reasons (Support for the Informal Seed Sector in Development, 2000):

1. The seed of landraces is readily available, and
2. Landraces are usually adapted to the local growing conditions, the low-input cultivation practices, and the needs of the farm.

Cyber-seed centers give relevant information about landraces and their importance for the communities (e.g. diversity of ecosystems, low-input systems, adaptation to the changing environment, disease resistance, health preservation, and nutritional elements).

CBSS is used in many African countries as a solution to the lack of quality seed. However, often technicians from government and project-funded programs do not leave the system to run by itself. They focus on technical aspects of the seed production such as the respect of isolation norms, roguing of off-types, cultural practices. Organizational, commercial and institutional aspects that can favor the development of formal well-structured enterprises are not taken into account. In particular, the reinforcement of farmers' capacity building at the grassroots levels and social traditional aspects are neglected.

Recognizing farmers' contribution can help upgrade the quality and the diversity of seed produced on-farm for on-farm use by individual farmers. Of course this will need adaptation of seed rules and regulations to local needs (Bèye, 2000; Bèye et al., 2009). The cases of Côte d'Ivoire and Senegal where the involvement of teams of ATs and QCFs in monitoring the quality of the seed are accepted represent good examples that need to be better explored. On that issue, Cromwell et al. (1993) call for the promotion of farmer-level seed production and the support of farmer-to-farmer seed exchange mechanisms.

Several initiatives were also tested in Europe through the organization in networks like the "Réseau Semences Paysannes" in France and the "Rete Semi Rurali" in Italy (Bocci and Chable, 2009). Their members are farmers, consumers, and scientists working together in order to reconsider the scientific, technical, and legal aspects of seed production by establishing links between varieties with the *terroir* defined by its soil, its climate, its people, and their history.

Starting from 1998, the European Union, concerned at the loss of agricultural biodiversity, proposed a new directive (98/95/EC) in which they envisaged the possibility of cultivating, exchanging, and selling varieties in danger of genetic erosion, known as 'conservation varieties', as well as varieties adapted to organic agriculture, and mixtures of species and varieties. These new approaches will surely influence the development of the seed strategic models.

## SEED STRATEGIC MODELS

Seed systems are run by using seed strategic models. The models are built based upon the roles of the different partners involved in the seed value chain and their know-how but also the value chain orientation. In general, five strategic seed models are identified:

(i) The seed sector is state-managed.
(ii) The seed sector is run by research and extension institutions.
(iii) The seed sector is run by private companies.
(iv) The seed sector is run by smallholder farmers.
(v) The seed sector is run by small-scale seed enterprises.

### Strategic model I

The seed sector is state-managed. Government interventions in the seed sector are favored mainly by the lack of a solid and well-organized private sector. The sector is usually subsidized at all levels (e.g. production, processing, certification, distribution). The focus on distribution, as opposed to marketing, does not facilitate the development of the seed sector. However, these interventions are worthwhile for a nascent seed sector and especially in countries emerging from civil wars or after disasters due to climatic catastrophes (e.g. droughts, flooding).

### Strategic model II

The seed sector is run by research and extension institutions. This is a research-led approach. It makes seed of improved varieties available at farmers' level directly from plant-breeding plots through the production of Breeder and Foundation seeds.

Through this approach, the whole seed system is controlled by the research and extension institutions. Local production and diffusion techniques are used (Jarvis et al., 2000). NSSs monitor seed production fields and seed stocks by spot-checking. Release aspects may face difficulties but can be improved during the experimental trials if participatory approaches (participatory varietal selection [PVS], on-farm field trials, demonstrations) are used efficiently by involving major partners (national seed and phytosanitary services), and end-users (farmers and the private sector).

This model is used in all cotton-growing countries in Western and Central Africa. The model is interesting as it ensures a regular provision of Breeder and Foundation seeds and in some cases. Registered seeds are also covered. The approach can be used as a transitory mechanism (until the emergence of appropriate seed systems) if seed certification mechanisms are implemented especially at levels of Foundation and, sometimes, Registered seed.

### Strategic model III

The seed sector is run by private companies. The model targets the development of a modern seed industry to African farmers through the development of national and regional competitive seed industries.

As stated earlier, there are more and more seed companies that are interested in working on rice. In the past, these companies focused mainly on maize and sorghum hybrids and vegetables. Now, the situation for

rice is improving because of the high demand for quality seed at national and regional levels. The harmonized rules and regulations in West and South Africa offer opportunities for the regionalization of the seed industries and the markets. ECOWAS and SADC regulations open a new avenue for variety release and seed trading in West Africa and South Africa.

Harmonized seed laws will likely facilitate cross-border movement of seeds and provide a broader market for seed enterprises. It will also play a key role in seed security if space is opened to farmers who can then save, use, and market their seeds.

The development of hybrid varieties may well open new areas of fruitful collaboration with smallholder farmers. It is expected that private companies will play a leadership role in the sector and will, at the same time, help to better structure seed production and quality control activities, operations related to information and marketing and food security.

### Strategic model IV

The seed sector is run by smallholder farmers. This is the case of local traditional seed systems, run by farmers themselves and partners that produce and market seeds, without direct control by government institutions that regulate commerce or seed activities. It is flexible and efficient for the diffusion of genetic materials.

The model was extensively used by many NGOs and development agencies at the end of the 1990s. Several initiatives were undertaken including the provision of quality seed, fertilizers, and pesticides. Farmers' groups were also created. However, initiatives stopped at the end of projects. It seems that the real constraints of the model were not well addressed. In fact, few studies are conducted to understand how to improve the functioning of the model, which is more development-oriented than market-oriented. Social, cultural, and historical aspects should also be taken into account.

### Strategic model V

The seed sector is run by small-scale enterprises. The provision of Breeder seed is part of the mission of centers' breeders – AfricaRice and National Agricultural Research Systems (NARS). However, NARS should be able to produce Foundation seed on request if they have sufficient financial resources and if regulatory procedures are respected (e.g. quality control and seed certification). In this case, they should make sure that the varieties are released according to the National or Regional regulatory procedures (harmonized rules and regulations are effective in West and East Africa).

It is noted that in most SSA countries there is no functioning seed release board. In this case, it is recommended that the stakeholders (including farmers, the private sector, and technicians from the NSS) involved in the PVS and on-farm trials should give approval for the release and the diffusion of the selected varieties after submission of the passport data of the varieties by the research institutes.

Both conventional and community-based seed systems can be used under this model for the provision of certified Foundation seed by research institutes and "Controlled" or "Seed of Acceptable Quality" seeds by small-scale enterprises. The approach offers good opportunities for smallholder farmers to get access to quality seed produced locally but also, to become better organized through the development of small-scale rural enterprises.

Rural enterprises are close to farmers and can help them to play a more consistent role in food security and in the preservation of the agro-biodiversity.

Agro-biodiversity provides a source of diverse materials that can help communities better face changing climatic conditions with their influence on the growth of (new) crop pests and diseases, soil erosion, changing market conditions, and increasing population pressure.

## WHAT ARE THE MOST USEFUL SEED STRATEGIC MODELS FOR THE DIFFERENT SEED SYSTEMS?

The five strategic seed models are all useful and can be implemented solely or in combination, depending on many factors that take into account the complexity of production/farming systems, the policy environment, socio-cultural aspects and market opportunities.

In countries where the seed sector is in the infant stage (as in most of the Central African Republic, Chad and countries recovering from recent civil wars – Liberia, Somalia, Sierra Leone, South Sudan), emphasis should be put on interventions from the governments targeting the development-oriented value chain (Model I).

In countries where the farming systems are characterized by multiple cropping and intra-crop diversity (many rice varieties in the same plot combined with other crops) and the use of farmer-saved seed due to the self-pollination characteristic of rice, models I, II and III seem to be more appropriate. In particular, in rainfed ecosystems, integrated seed systems should be promoted. As stated by the USAID[4] study on seed value chain (USAID Economic Growth Project /Senegal, 2009), in such systems the added value is low, and it is preferable to first target the strengthening of local seed systems by empowering technical, organizational, and managerial capacities of smallholder farmers. Model IV also seems here appropriate as it promotes the leadership of the smallholder farmers. Successful results were obtained through this model in Burkina Faso and Mali for the production of maize seed.

[4] United States Agency for International Development

In areas with high irrigation potential and where real economic profits can be made in the rice value chain, model V promoting private seed companies can be explored (South Africa, Nigeria, Uganda, and Kenya). In those areas, focus should also be put on the development of the traceability, and market and information skills.

Whatever happens, countries should be careful in not looking at the seed systems as business tools only but rather as vehicles of civilization integrating the past and the present of a selected community at different levels (scientific, historical, social, cultural and economic).

Seed should be seen as a product of the civilization which is destined to ensure food security, the sustainability of agricultural systems and the enhancement of biodiversity. That means seed strategies should be designed to be central to farming systems rather than the simply adding value (Bèye et al., 2013).

Seed systems should offer a range of possibilities that aim at making farmer seed available at the community level while conserving agro-biodiversity and promoting rural innovations that are in phase with socio-cultural dimensions.

In the case of CBSS, seed systems are first analyzed at the grassroots level. From there, seed systems are built based upon the improvement of the local farming systems, the exploitation of modern as well as local traditional varieties, the reinforcement of traditional seed diffusion networks and their linkages to the *terroir*.

The concept of *terroir* embraces different components that give value to the seed at different levels (agricultural, environmental, nutritional, historical, social, cultural and economic) and its role within the communities. This is not easy to capitalize but researchers should know that the sustainability of the seed systems depends on the level of integration between all these components. This, of course, goes beyond the seed value chain, which looks mainly at the economic and financial profitability and at the risks foreseen.

## CONCLUSION

The African community should realize that seed systems can be built only through a long process endowed with conducive policy and appropriate delivery mechanisms.

The recent 2008 food crisis has led the international community via the Governing Body of the ITPGR to encourage countries to remove barriers to the saving, exchange or selling of seed by directly supporting farmers' seed systems. The African Union for its part has developed an African Model of Law which aims to protect breeders and, at the same time, farmers' rights.

These initiatives are reminiscent of those taken by India in 2001 through the Protection of Plant Varieties and Farmers Rights Act which gives possibilities of protecting plant varieties while enabling farmers to save, re-sow, exchange, and sell new plant varieties developed by farmers and breeders. The case of India is interesting as it favors: (i) close collaboration between farmers and breeders; (ii) the development of participatory approaches (participatory varietal selection – PVS, participatory plant breeding – PPB) and (iii) the release of varieties coming from these approaches.

After more than 50 years of trial and error, perhaps it is now time to go for "crash programs" that will allow farmers to have access to quality seed. It is observed that in Europe as well as in Asia, the development of the seed sector was enabled first by a strong commitment of governments through adequate policies including subsidies, credits, and markets. It is obvious that for a crop such as rice, which is self-pollinated and easily reproducible, the development of the African seed sector will definitely need assistance from governments and the recognition of locally produced seed.

It is clear that farmer-saved seed and farmer-to-farmer seed exchange will remain the primary source of seed supply for the majority of farmers for many years. According to Bay (1997), farm-saved seed is a common feature of agricultural systems worldwide, particularly in self-pollinated crops and/or those systems where hybrids are not used. He estimated that in the mid-1980s, more than 35% of seeds planted were farm-saved (in the USA, for example, about 75% of seeds of self-pollinated crops like wheat, barley, and oats were farm-saved, while in Europe similar figures could be found).

Referring to the complexity of the issue that will need flexible seed policies, it is recommended that a transition period of 5 to 10 years should be observed. That period will be used to:

1. Learn more about: (i) Local farming systems and their adaptation in this challenging climate change environment; (ii) Farmers' seeds and their role in ensuring food security and enhance the agro-biodiversity in SSA; (iii) Impact of international rules and regulations on the development of the seed sector in SSA; and (iv) What the threats to the lack of room for farmers to produce, multiply, use, exchange, and sell the seeds of plants cultivated in their own fields are.
2. Build fundamentals of sustainable seed systems through: (i) The structuring of the seed sector and the creation of appropriate conditions for incorporating local indigenous knowledge into the national regulations. It is disappointing that farmers' rights are not taken into account in SSA; (ii) Reinforce traditional seed diffusion mechanisms in small farmer communities (Cromwell, 1990); (iii) Create conditions for all the interested private operators to develop seed industries that respect farmers' rights including the rights to cultivate and sell their own local varieties enriching by the same time the agro-biodiversity; (iv) Ensure the foundation of food sovereignty.

At the end, the most important action is to reinforce the

capacities of the small-scale farming systems to become stronger and sustainable. That means more diversified production, more biodiversity, and more income at community level but also, more employment of young boys and women in the rural areas and in the long run, the establishment of food sovereignty though the autonomy of the local seed systems.

The autonomy of the local seed systems will likely offer to the communities the possibility of self-regulation, through the progressive adjustment of cultivation practices to different regions and to climatic variations.

Autonomy will also allow the adaptation of the cultivated biodiversity to socio-economic and cultural changes, and to the needs of the human society that tends to it (de la Perrière and Kastel, 2011). It will help to break the barriers between the different seed systems while facilitating the appropriation by farmers of the best technologies for themselves and their communities. A better comprehension of sociological, ethnographic, humanistic (gender, ethnicity and history), environmental, and economic aspects of seed issues will be fundamental to shape appropriate seed systems targeting sustainability of the farming systems and food sovereignty.

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