HOW FARMERS USE AGROBIODIVERSITY TO COPE WITH CLIMATIC VARIABILITY AND COMMUNITY CHANGE

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Abstract

Small scale farmers commonly use agrobiodiversity as a way to maintain the quality of their livelihood. Agrobiodiversity practices are more frequent in tropical low input agriculture but are also present in Europe. This paper first describes how farmers in Mali use more than 200 traditional varieties of sorghum in an area covering over than 1 million ha altogether, and how their photoperiodism allows reduction of drought risks and other risks. The second case presented concerns an area of 10 000 ha on a volcanic slope in the Comoros Islands where in recent years, farmers have increased agrobiodiversity by using multiple cropping including trees. Their main motivation has been to cope with population increase in an inextensible area. The general discussion concerns the methodological approach, the reasons why agronomists should have more consideration for farmers' practices, and how agrobiodiversity on small scale farms in Africa and in Europe preserves resilience and opens up an alternative in certain situations to high input farming systems.

Key Words: Biodiversity, Ecosystem, Farmer's practices, Resilience

Introduction

The concept of biodiversity has been used in the European scientific community following the adoption of the International Convention on Biological Bioversity in 1992. Numerous studies are now available on the characterization of the three components of biodiversity: genetic, specific and ecosystemic. But little has been investigated on agrobiodiversity, in particular there are few descriptions on how farmers use agrobiodiversity and few investigations proving that agrobiodiversity can permit them to cope with environmental constraints. To contribute to answer of these questions this paper presents two case studies : One on sorghum and millet ecotypes in Mali, in the semi-arid tropics of West Africa, and the other on multiple cropping in the Comoros Islands between Madagascar and Mozambique.

In both Mali and the Comoros, farmers work in a risky environment linked to poverty and low commercial inputs. In the Comoros Islands the stake is to increase production of agroecosystem to feed an increasing population on an area limited in size. The challenge for the farmers is to increase the specific biodiversity of species within the agroecosystem. In Mali where sorghum is a staple food the stake is to increase production of the agroecosystem despite rainfall variability, pest attacks, etc. In this situation the challenge for the farmer is to improve the productivity of his ecotypes without loosing their adaptation to the constraints of his agroecosystem

This paper will present how farmers use agrobiodiversity, as well as the ecosystemic or economical reasons of this utilization identified by agronomists. To point out some of these reasons we have characterized the relations between specific biodiversity and ecosystemic biodiversity, as recommended by Barbault, (1997).

The two cases selected are not located in Africa by coincidence: biodiversity is a main feature of African agriculture. In Europe, the situation is different. European farming systems were initially very diversified, but agriculture has been intensified progressively in many regions for more than a century. Furthermore, there is growing concern today in Europe about the negative effects of intensive agriculture, especially when natural or economic resources are not adequate. So through the cases presented European farmers could find or rediscover how utilization of agrobiodiversity could help them cope with their environmental constraints.

Farmers and biodiversity of sorghum ecotypes in mall

Production of sorghum in Mali increased 6% per year, a higher percentage than population increase from 1985 to 1995 (FAO, 1997). This surprising favorable tendency is due to the extension of surface. Ninety per cent of this area is cultivated with traditional varieties. The same tendency is observed for millet, and what can be said for sorghum is more or less valid for both crops.

Utilization of sorghum agrobiodiversity by farmers

Traditional varieties of sorghum cover a large spectrum of growth patterns and agronomic and seed qualities. But until very recently breeding programs have ignored this biodiversity of the ecotypes. Moreover some genetic characters in favor of resilience such as photoperiodism, thought to limit grain yield, were eliminated in the new lines without enough caution. It is to clarify this contradictory situation that we describe how farmers use the agrobiodiversity of sorghum and what its advantages are.

Farmers use ecotype biodiversity differently locally and regionally. Locally, on his exploitation, the farmer plants more than four traditional varieties selected by him or his ancestors. Each variety corresponds to different objectives. such as adapting to the intra diversity of his landscape (like taking advantage of soil humidity on low slopes), bridging the gap between two harvests, producing sorghum for beer (*dolo*) or sweet sorghum, etc. To attain these objectives the length of cycle duration is one of the characters of the varieties chosen by farmers, (Ouattara, al, 1994).

Regionally, utilization of sorghum agrobiodiversity is different. Traditional varieties of sorghum approximately cover an area of about 1 million ha (1992-94). In 59 villages 193 varieties has been collected (Clement & Leblanc 1978). So the number of varieties used by farmers is certainly higher than 200. The reasons for this large number of varieties and why farmers did not homogenize them between villages is not well documented. It is only after that the links between the variability of seasonal rainfall and the variability of cycle duration of varieties, has been elucidate, that the interest of farmers for the agrobiodiversity of sorghum became clearer.

Minimization of farmers' risks due to rainfall variability.

Rainfall regime variability of agroecosystems

The beginning and the duration of the rainy season are two variables which are significant for the farming system and they were thus selected to evaluate the spatio-temporal variability of sorghum agroecosystems on a regional scale.

Temporal water regime variability of the ecosystem

In the example of Segou for 1950-1990, the range of dates marking the beginning of the rainy season is striking, covering more than two months between June and August. The duration of the rainy season also varies drastically between 60 and 140 days. These two variables are linked because the end date of the rainy season is more stable than its beginning.

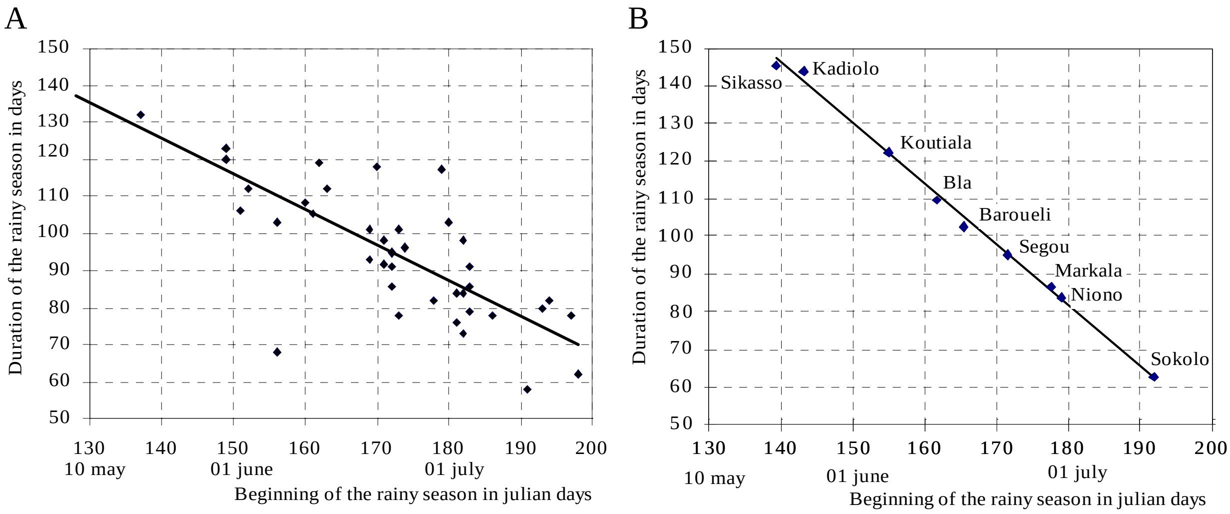

Figure 1– During the1950-1990 period, relationship between the beginning and the duration of the rainy season in Mali: (A) *temporal*, at Segou, (B) *spatial*, between 9 climatic stations spread over a transect through the sorghum region.

Spatial water regime variability of the ecosystem

The range of spatial variability of the length of the rainy season is quite important among the 9 climatic stations in the sorghum region. From north to south it varies from almost 2 to 5 months (figure 1B). By coincidence the temporal variability in Segou between 1950 and 1990 falls in the same order.

Variability of cycle duration of traditional sorghum

The two main factors responsible for cycle duration variability in traditional sorghum are photoperiodism sensitivity and time of sowing (tested experimentally by observing the heading date for two dates of sowing). The traditional varieties were collected in cooperation with farmers on the same transect as for the climatic studies. An increase from north to south in cycle duration and in ecotype photoperiodism sensitivity is observed (figure 2). The flowering time of an ecotype is almost independent of the sowing date and depends mainly on the day length at the end of the rainy season. The variability of this date is high from north to south but low between years

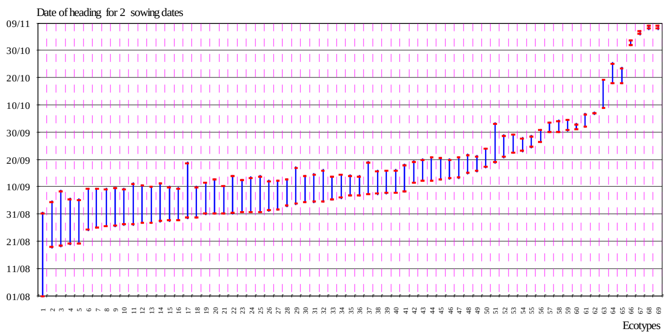

Figure 2- Diversity of heading of ecotypes sown experimentally at the same location on 13 June, and 15 July. These ecotypes are the main traditional varieties used today by farmers. Each number is an ecotype classified on a north-south transect of Mali by the latitude of the sampled farm.

Synchronicity process

By comparing the variability of the duration of the rainy season and the duration of the cycle of sorghum ecotypes, a strong relationship appears (figure 3) ,called “synchronicity”. The same relationship has been found for millet (Kouressy et al., 1998).

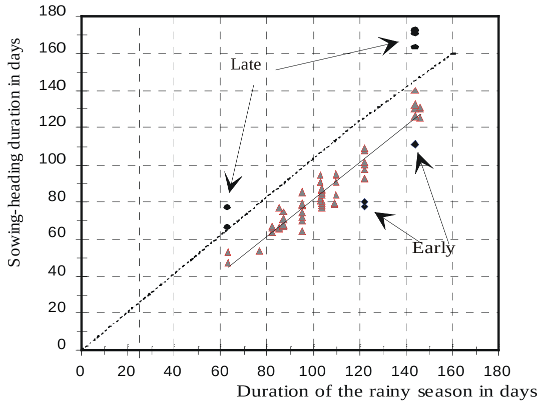

Figure 3- Synchronicity between rainy season and ecotype cycle duration . North-south transect in the sorghum and millet region of Mali.

Synchronicity reduces risks

The advantage of synchronicity between local ecosystems and local ecotypes is to provide farming systems with a higher resilience, through risk reduction (figure 4). Local ecotypes, compared to improved varieties with fixed cycle duration, reduce three main risks:

- drought or excess of water impact, thanks to better use of available rainfall,
- soil degradation, thanks to a reduced period of bare soil and consequently less runoff and leaching.
- economic risks, by reduction of production costs, thanks to more straw production used for manure and to feed cattle and draft animals.

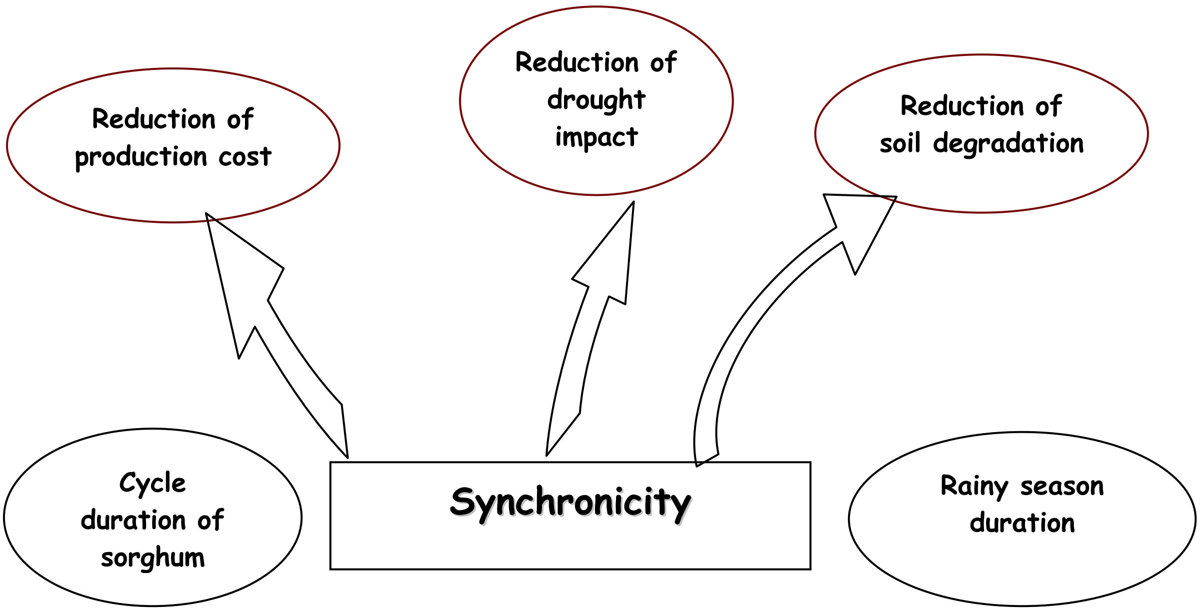

Figure 4 Synchronicity between rainy season and ecotype cycle duration. Effects on farming risks.

Conclusion on the use of agrobiodiversity by farmers in Mali

Farmers have always used a large number of ecotypes of millet and sorghum. These cover a large variability in cycle duration due to their different sensitivity to photoperiodism Thanks to the process of synchronicity the agrobiodiversity of ecotypes is an exceptionally efficient means of adaptation to rainfall variability which can affect not only crop production but the potential of the land. Therefore farmers have clearly shown that by their utilization of agrobiodiversity they contribute to the resilience of their land. This would not have been the case if they had used only a few cultivars had been used for the entire sorghum region. Of course increasing yield has to be an aim for farmers as well as for agronomists. To conciliate both objectives a multidisciplinary program was launched in 2002. His objective is to maintain photoperiodism trait in higher yield varieties (Trouche *et al,* to be published). A participatory approach between farmers and scientists will adapt selected varieties to the diversity of agroecosystems and the objectives of the farmers..

Agrobiodiversity used by farmers for intensification of land in the Comoros Islands

Niumakele, the southern region of Anjouan Island, is generally believed to be the poorest and the remotest area of the Comoros Islands, although this area shows, if closely observed, some positive changes (Sibelet, Divonne, 1997). Although population density is as high as 600 inhabitants per square kilometer, the rural population has been active for decades, in spite of demographic pressure and economic crises. From 1965 to 1990, the people of Niumakele have increased food production 2.7 fold while the population only doubled (Sibelet, 1995).

Diversification appears to be an important factor explaining this improvement.

The present, sociological study, focused on people and communities, and not only on development project goals. While many experts repetitively described the failures of existing actions sustained with artificial means such as wages for farmers, we chose instead to follow the advise of the sociologist Ballandier (1983) and look for “inside dynamics”. It means to listen and observe people, especially, explaining the changes in their life and their farming systems. In the case of Anjouan, these farming systems changed a lot. These changes were invisible for experts who were waiting for the changes they suggested from 1960 to 1975, preventing them to see the indigenous processes of innovation. An other point impelling observers to recognize changes in a society is what Hirschman (1968) calls the “persistent marks” which don't change although all the rest does change.

Comparison of the evolution of ecosystemic and specific diversity

An increase in the number of multiple cropping associations and the number of species grown in each association reveals that farmers have developed varied agroecosystems. (table 1)

Since the 1960’s, rice yields have been decreasing. In reaction farmers stopped rice cultivation and introduced or developed crop associations with more plant species, especially trees. Farmers originally associated two to four crops in the same field. Now they still have this kind of crop association, except for rice, plus many other crop associations in which trees are more numerous in quantity and in quality. Fields contain cassava, cocoyam, corn, bananas, *Cajanus cajan*, *Casuarina equisetifolia*, fruit trees, clove trees, Ylang-Ylang *(Cananga odorata)*, etc. Some fields of a quarter of a hectare each, contain more than thirty species with unusual ones such as cinnamon and ginger.

Table 1: Ecosystem Diversification by multiplication of crop associations

Location		Crop associations	
Position on the water shed	Distance to the village	Before diversification (1965)	After diversification (1990)
HIGH LANDS	NEAR	Rice, Corn, *Cajanus cajan*, Sweet Potato1	Cassava, *Cajanus cajan*
			Cassava, Corn, Cajanus cajan, Sweet Potato
			Cassava, Corn, *Cajanus cajan*, Sweet Potato, Banana
			Field fertilized by a cow with 10 to 40 species with living hedge 5 A
	FAR	Cassava, Corn, *Cajanus cajan, Phaseolus mungo*3	Clove tree or Ylang-Ylang and fruit tree + Cassava B
LOW LANDS	NEAR	Rice, Corn, *Cajanus cajan, Phaseolus mungo*2	*Cajanus cajan, Phaseolus mungo*
			Cassava, Corn, *Cajanus cajan, Phaseolus mungo,* Banana
			Field fertilized by cow manure with 10 to 40 species with living hedge5 A
	FAR	Cassava, Corn, *Cajanus cajan* 4	Cassava, Corn, *Cajanus cajan*
			Ylang-Ylang and fruit tree B
		Coconut	Coconut C

12345 *and* A B C *will be used in tables 2 and 3 as references to table 1*

Complementarity within ecosystemic diversity

On the plateau at 700 meters, houses and their home-gardens have been enclosed with “living hedges” for more than a century. For three decades now, enclosures of living hedges have been spreading over a third of the village land. Livestock farming and cropping systems have been intensified by a complex system of innovation based on three major components: living hedges, cattle fertilization, and a new cropping system (Sibelet, 1995). Farmers have planted living hedges around one or several fields. Cow manure fertilizes the soil and allows a diversification pattern in which tubers and trees are dominant. This new system allows continuous cropping all year long whereas in the old system, rice had to be sown and cultivated at fixed times.

On sloping land away from the village, trees are dominant : clove trees and ylang-ylang (*Cananga odorata*). At the periphery of village land along the coast, coconut trees dominate. In the new system, cropping intensity is higher in the first circle while it is lower in the second and the third circles of the territory (table 2). In each circle (plateau, slopes, periphery), we present the most representative associations (mentioned as A B C in tables 1 and 2). Furthermore, circles 2 and 3 produce fodder for the cattle which is located mostly in circle 1.

Table 2 : Evolution of crop rotation : number of cropping years / (number of cropping years + number of fallow years).

Circle		Before innovation	Since innovation
1. Plateau	A living hedges	2/3	¾ or permanent
2. Slopes	B Slopes with trees	2/3	1/3
3. Periphery of village	C Coconut area	2/3	1/3

A B C see references in table 1.

Positive effects on food production and on the environment

Overall production is higher in the new system (table 3). Thus an intensified field (i.e. with a living hedge, fertilized by manure from one cow, with three years of cultivation followed by one year of fallow, mostly with tubers, banana and trees) produces ten-fold the amount of a field with a traditional crop association of rice, corn, *Cajanus cajan* with two years of cultivation followed by one year of fallow.

The system based on Cassava produces globally five times more than the system based on rice. Compared to the initial situation altogether, production has increased 2.7 fold near the village and less at the periphery but complementarily. This increase took place from 1965 to 1990 while the population of Niumakele doubled. The end result shows an increase in work productivity per inhabitant as well as an increase in land productivity.

Table 3: Production of the main systems (Comorian Francs per hectare).
Comorian Francs (FC). 100 CF = 0.3 Euros.

TYPE of SYSTEM	**Crop associations**	**Income CF/ha**
SYSTEMS BASED ON RICE	1 Rice, Corn, *Cajanus cajan* of the highlands	150.000
	2 Rice, Corn, *Cajanus cajan* of the lowlands	120.000
SYSTEMS BASED ON CASSAVA IN A FERTILIZED FIELD	3 Cassava, Corn, *Cajanus cajan* (> 200 m)	710.000
	4 Cassava, Corn, *Cajanus cajan, Phaseolus Mango* (< 400 m)	477.000
HIGH-FERTILIZED SYSTEM	5 Cassava, Cocoyam, Banana, Corn, *Cajanus cajan*, various trees	1.210.000

12345 see references in table 1

The new system is more environmentally friendly. If increasing agrobiodiversity can lead to intensification, it also has favorable consequences on the sustainability of the ecosystem. Living hedges were planted firstly to keep out neighbors' cows, while they now protect cows and the various new crops inside the fields from thieves. The living hedges efficiently reduce land erosion, a phenomenon often underlined by agronomists in such areas. Living hedges produce fodder, firewood, service wood, etc. thus reducing the pressure on the rare forests in Anjouan.

Conclusion on farmers use of species biodiversity in Comoros Islands

For three decades now, farmers have increased their food production while strengthening the sustainability of their ecosystem in a context of demographic increase. For this change, farmers have combined several components to develop an alternative to intensification as proposed in the 60's and 70's by the extension service. The technical package promoted in the sense of a green revolution was refused. Farmers have recombined their own practices; they use their ancient plant species in another way or they associate livestock and cropping. They also use some components introduced by the extension services but in another way. For instance *Gliricidia sepium* and *Pterocarpus indicus* promoted as stakes for vanilla beans are now the main trees forming living hedges. So farmers have efficiently increased agrobiodiversity and this increase is an actual component of their alternative intensification.

Discussion and Conclusion

Farmers can use agrobiodiversity efficiently and agronomists can explain why. These points are the most important in the analysis of the two cases presented. This should be discussed through questions like these (i) do the utilization of agrobiodiversity by farmers deserves more investigation in the context of farming system research and extension? (ii) At the local level when, where and in what economic and other conditions can farming systems using agrobiodiversity compete with alternative farming systems using a higher level of inputs? (iii) Correlatively what criteria should be used for the comparison? (iv) Rather than mainly use biomass production like for mixed cropping in Europe (Loreau, Hector, 2001) would not it be preferable using multiple criteria associating farmers' objectives, and agroecosystem constraints ?

To build answers to these questions we propose that agroecosystem be considered as a kind of meta resource providing, natural resources like water, tree, etc. The state of the agroecosystem depends on the farmers knowledge and practices. Diversity of agroecosystem and crop production are linked. This functional notion should be discussed with different specialists of agronomy and notably with economists. The task is to build a common concept for identifying processes, such as synchronicity, to build plain indicators for managing interactions between biophysical and socio-economical factors.

Furthermore, the study of the functioning of agrobiodiversity by analyzing the links between its three components will answer to some critics on the superficial implication of farmers in participatory approaches (Lavigne-Delville, al. 2000). In our proposal, farmers practices are first objectively observed, and then only, the analysis of agrobiodiversity is implemented to explain their practices. Then by sharing their specific knowledge, farmers and specialists in agronomy create conditions for a dialogue to design decision support tools with modern information technology combining adapted models and environmental data bases to manage biodiversity.

For European small scale farmers and local communities where sustainability and risk reduction are at stake, agrobiodiversity could be an option, as shown by Wood & Lenne (1999). More generally, in the future, agrobiodiversity may stand out as an efficient option for taking up the challenge of agricultural production in the face of globalization.

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