Local *Dioscorea sp* production systems and their potential for agroecological practices in the central part of Cote d'Ivoire

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Abstract: *Producers in West Africa increasingly have to cope with climatic hazards, land pressure, and declining soil fertility. A major concern is the search for intensification methods adapted to various environments and types of farmers in order to ensure food security as well as a sustainable management of natural resources. Farmers have to innovate according to their constraints and priorities. Yam, Dioscorea sp., is emblematic of this quest. It has a high socio-cultural and economic value in West Africa. Its production systems were based on long natural fallow. Nowadays local yam-based production practices have to be adjusted to rapid changes using integrated soil fertility management. The paper presents and discusses the result of a reference study conducted in the northern Côte d'Ivoire nearby Tiéningboué, on agroeconomic and institutional factors affecting yam-based cropping systems and their influence on fertility management. A Rapid Rural Appraisal was conducted in July 2015 in the area and case studies in three villages in March 2017 by a multidisciplinary team (socio-anthropologists, agroeconomists and agricultural technicians). Changes in the landscape combined with characterization of cropping systems are described and assessed on the agroecological characters of yam-based production systems in Tiéningboué. Many of recent adjustments in technical and institutional practices tend to misdirect cropping and production systems away from agroecological principles. Nevertheless, there are opportunities for adaptive management of farms towards agroecology. Such an adaptation of agricultural practices, production of knowledge and reduction of uncertainty requires an iterative learning process and the involvement of a diversity of local and externl stakeholders.*

Keywords: *Agricultural production system, Dioscorea sp, technical innovation, adaptive management, agroecological practices*

1. Introduction

1.1. Problematic

Agricultural farming systems in West African countries are still extensive but submitted to rapid changes. The question discussed here is how far the transitions observed match with agroecological principles. We take the case of yam-based farming systems. Such systems mimic nature in land abundant contexts and seem to comply with agroecological principles. However, when land becomes scarce and when yam production moves from the forest to the savanna regions, producers have to reorganise their systems completely. We compare the idiotypical initial state with the observed farming and cropping systems in the central part of Ivory Coast, discuss the relevant indicators for an agroecological assessment, depending on the definition of agroecology, and sketch an evidence-based approach for this system assessment. Recommendations for research and extension are discussed out of the evidence already gathered.

Sub-Saharan agriculture faces increasing climatic hazards and a soil fertility decrease. In West Africa, the increase in crop yields cannot keep pace with demographic growth and new land is continuously being cleared. Traditional farming systems relied on natural fallow for the replenishment of soil fertility and on the maintaining of a high diversity of crops in short rotations to cope with pest and climatic hazards. They now have to adjust to lower land and labour availability, a demand for less tedious and more mechanized tasks and new markets requirements in terms of products and varieties. Therefore, rural development and research actors are concerned with adapted intensification pathways. At the same time, lessons have been learnt from chemical-based intensification and inadequate mechanization in developed countries, which have caused ecosystem disruptions and long term environmental damages. Adaptive management of farms towards agroecological practices may be an option to consider when researching for more efficient production systems ensuring the sustainable management of natural resources .

1.2. Agroecology as an option for a transition to new farming systems

Agroecology makes a plea for agricultural production systems based on ecosystem processes and functions, while industrial agriculture resulting from the agricultural revolution or the Green Revolution builds on outputs out of external inputs.

Agroecology is still a fuzzy concept, often declined in three dimensions, as a science, as set of management practices and a social movement ethic. Agroecology as a scientific discipline is concerned with the study of agroecosystems and the application of ecological knowledge to agriculture. Starting from the definition of Miguel Altieri in 1995, this science, of biophysical nature in the broad sense, deals with the accumulation of knowledge about the functioning of (cultivated) ecosystems.

Agroecology also deals with management practices that allow for a sustainable yet productive agriculture by mimicking the natural ecological systems of the specific site, by promoting self-regulating processes enhanced by a high natural and cultivated biodiversity and a low farm specialisation (multifunctionality) as well as by promoting in situ conservation and recycling of resources rather than continuous external input supply combined with soil and natural resource degradation.

For Dupraz (2005), agriculture had to evolve in the long term from the logic of land and natural resource use to a logic of "management of cultivated ecosystems". Farms should rely on adaptive management, which is an iterative learning process based on the constant monitoring of the agroecosystem to adapt farming practices, produce knowledge and reduce uncertainty (Thoyer et Le Vely, 2017). Especially in unfavourable environments where the use of external chemical inputs is restricted, the design, creation and adaptation of complex and productive systems require the active producers' participation and local knowledge mobilisation (Wezel et al., 2009). In all, agroecology is knowledge-based.

The third dimension of agroecology is its social movement character. In Latin America, social movements[1] engaged in agroecology for the autonomy it confers to small farmers, its recognition of farmers' knowledge and know-how and its holistic approach. Agroecological movements attach a great importance to issues of food sovereignty and food security, rural development and farmer autonomy (Martinez-Torres and Rosset, 2014)).

However, producers will not improve their livelihoods through agroecological practices only. They also have to control sets of essential and multidimensional assets, and in return these assets condition their ability to implement such practices. An agroecological assessment of agricultural practices may require the integration of ecological, economic and social dimensions into the analysis of agrarian or food systems (Francis *et al*., 2003). Agroecology is therefore increasingly considered a transdisciplinary approach (including agronomy,

[1] *This is the case, in Brazil, of the movement of alternative agriculture and the movement of the landless, who note in the years 1980-1990 the incapacity of the peasants to get out of misery, even after the access to the because of too little production and an inability to buy inputs. They then turn to agroecological practices*

ecology, humanities and social sciences), also taking into account local knowledge in system analysis.

Authors assert the wide adoption of agroecological land management principles. In a context of generalized environmental crisis, principles respecting an environmental ethic, ecological principles and an affective relation to nature, perceived as mother and nurturer, are gradually rediscovered by large number of human beings. This is particularly visible in agriculture. An increasing number of farmers succeeds in improving yields and maintaining them by using methods based on proven agroecological principles emphasizing diversity, synergy, recycling and integrated management of resources as well as participation and strengthening of the community. Harvests increase, biodiversity is preserved, and soil fertility restored by turning to appropriate and inexpensive technologies (Madeley, 2002). In Mali and Burkina Faso, for example, the widespread application of new water harvesting techniques is enabling farmers to take better advantage of rainfalls. The challenge of sustainable agriculture to maximize the use of local renewable resources seems to be met and (Pretty, 2003) points out the impressive rise in agricultural yields associated with this approach to agriculture. »

1.3. Context

Côte d'Ivoire is a West African country with a total labour force of 8,016,058 people (World Bank, 2017). The rural population is estimated at 49.7% of the total population, with agriculture being the main activity, accounting for 23.44% of Côte d'Ivoire's gross domestic product (GDP) and employing 67% of the active population. The main export products from agriculture are cocoa, coffee, rubber (latex), cotton and cashew. Beyond export crops, food crops are not marginal, especially in the root-tuber-plantain group. Yam (Dioscorea sp.) is the country first crop in terms of volume because of its socio-cultural and economic value. It is traded on domestic markets and exported into the region (especially Mali).

97% of world yam production comes from Africa. Ivory Coast, which is located in the yam belt comes third with a production of 5,952,685 tonnes for harvested areas of 993,453 ha, and an average yield around 6 tons / ha (Faostat, 2017). Two main species are cultivated in West Africa: *D.rotundata* and *D.alata.* Both are major sources of income for producers with price ranging from 75F to 325 FCFA per kilogram according to location, variety and time.

As long as forest land is available, producers clear new land for yam but when there is no more forest land available they have to modify their cropping practices but at the cost of a yield decrease. Yam is a labour demanding crop and its profitability is at risk when yields tend to decrease. Yam potential yield is estimated at more than 50 t ha-1 (Tittonell and Giller, 2013)). Main causes of a yield gap are a decline in soil fertility, inadequate plant nutrition, poor seed quality, high pest pressure and a limited or a loss of production potential of traditional varieties (Lebot, 2009; Frossard et al., 2017). The project "Biophysical, Institutional and Economic Determinants of Sustainable Land Use in Yam Production Systems for Improving Food Security (Yamsys)" intends to tackle these issues. It is a transdisciplinary project based on a partnership between institutions in Switzerland (ETH, FiBL), Côte d'Ivoire (CSRS, UFHB), Burkina Faso (INERA, IDR-UPB), Benin (UAC - LADYD) and two CGIAR institutions (ICRAF, IITA). The project main objective is to develop sustainable soil management innovations in yam production systems in West Africa to improve food security, farmers' incomes and environmental quality. Its specific objectives are: i) to describe the sites at the beginning of the project, ii) to develop integrated soil management strategies in yam production systems, iii) to facilitate the adoption of innovations in integrated management of soil fertility in yam production systems; and iv) to communicate and apply the results of the project. The research is conducted on two (2) pilot sites in Côte d'Ivoire (Liliyo and Tiéningboué) and two (2) other sites in Burkina Faso (Midebdo and Léo) located on an agroclimatic gradient. Tieningboué is located in the vicinity of Bouaké within the guinea savanna zone. It is now a main yam production area.

The present paper is drawn from the reference study at the Tiéningboué site in Côte d'Ivoire. Its objectives were to describe socio-economic and institutional factors affecting yam-based cropping systems and their influence on soil management and soil fertility. Specifically, this paper will assess how far yam-based production systems in Tiéningboué fit with agroecological principles. Production systems are described in order to inform agronomic and ecological research is conducted on yam in West Africa by the Yamsys project.

The paper starts with the selection of management principles out of the agroecological theory and highlights potential options towards agroecological production systems capable to sustain their agroecological, economic, environmental and social performances.

2. Methodology

2.1. Framework for an agroecological assessment

Some generic assessment principles can be derived out of agroecology. Altieri (1995) proposes five (5) principles for developing agroecological practices, and therefore for assessing them: allow the recycling of biomass and nutrients; maintain favourable soil conditions for plant growth by maintaining a sufficient level of organic matter in the soil; optimize the use of resources (water, soil, light, nutrients) and minimize their losses; increase the diversity of species and cultivated varieties, in space and time; promote positive interactions between the different organisms present in the agroecosystem.

Generic principles can also be derived from ecosystem analysis to recognise and enhance ecological processes at work to obtain a sustainable and high production for the smallholders as well as ecosystem services, and to understand how to bring the system to adjust quickly to stress or a shock back to its initial situation or towards a new acceptable one. Agroecological practices enhance beneficial interactions and synergies among the components of the agroecosystem and thus reduce dependency on external inputs.

From the agroecology as a movement, an indicator is the autonomy which is conferred to producers becoming independent from external inputs, seeds tied to firms by individual property rights, and the accessibility even to the asset poor (Altieri and Toledo, 2011).

Following indicators are considered in an assessment framework suitable for yam producers in Ivory Coast:

- Sustainable soil management reducing nutrient losses, enhancing natural processes of nutrients inflows and recycling and promoting biological activity
- Pests and weeds management through smart vegetation management such as mixed cropping, smothering crops, etc.
- Biodiversity maintenance (cultivated and natural) through the diversification of species, the preservation of their genetic diversity, and the tolerance of wild species on cultivated plots
- Spatial and temporal crop patterns and further activity arrangement and interactions for balanced seasonal labour, land demand, food and cash supply as well as low susceptibility to interannual variation factors (such as climate and price stress and shocks)
- Local knowledge preservation through the display of its value and knowledge enhancement through exchange with a wide range of diverse yam stakeholders (including traders, researchers, yam growers from other regions, etc.)
- Social autonomy through a low indebtment by traders and microfinance institutions, security of land rights and aptitudes to cope with crisis without cutting essential costs

and assets (soil fertility and natural resource “mining”, productive assets sales, cuts in household children education and health expenditures)
- Agreements conducive to sustainable resources use between resource traditional administrators (autochthonous landowners) and users.

2.2. Systems under consideration

There is a wide variety of definitions of agricultural systems. They may focus on different aspects of a system such as the interactions between systems and system components (Shaner et al 1982) and on the complementary between biophysical and socio-economic processes (Norman et al 1982). The functioning of any individual agricultural system is strongly influenced by its external rural environment, including policies and institutions, markets and information links.

Systems that have to be considered to assess agroecological practices are the cropping systems in the first place. Cropping systems are shaped to a large extent by agroecological factors and by the farmers management knowledge of these factors, which can be described as a succession of operations towards a harvest (the francophone “technical itinerary”) as well as by the spatial and temporal organisation of crops in fields, which affects soil fertility, adaptation to climatic uncertainty, pest and weed management, labour organisation, etc.

Cropping systems however are influenced by the higher systems they are embedded in. In order to account for cropping practices within the complexity of farm operations and to explain their logic, production systems also have to be grasped (Tittonell et al., 2010). More, understanding farmers' productive practices in a context where non-farm activities also are important requires to consider both farm and non-farm activities within activity systems, as they both influence labour allocation (competition or complementarity) as well as access and use of farm assets.

Agroecosystems should also be considered at a higher landscape level (Tscharntke et al., 2005). Landscape is the level where aggregated outcomes of cropping practices may become visible (for example erosion), interactions between agricultural and natural ecosystems perceived, and where positive and negative ecological externalities from agriculture and its ecosystem services can be measured. Ecological system properties such as homeostasis as a condition for resilience can also be better assessed at a landscape than at a farm level.

Historical patterns of change within agricultural systems can also be better assessed at this landscape level. Comparison over time and regions reveals differentiation mechanisms and helps identify the different production systems and the sets of agricultural management practices involved (Deffontaines, 1973; Deffontaines and Petit, 1985; Deffontaines, 1997).

In the end, hierarchies of systems can be studied in iterative analysis revealing the dynamics of the agriculture under study. Agrarian systems interact with regional agroecosystems; agricultural activity systems interact with their actors, among others, farmers; production systems interact with cropping, livestock or non-farm systems that compete for the allocation and use of farm resources (labour, land, equipment, technology). Within cropping and livestock systems, agricultural practices reflect how farmers meet their objectives under constraints mobilising their assets and their local knowledge in particular. By doing so, farmers shape their agroecosystems, which in reaction provide them with natural resources and ecosystem services.

Production systems differentiation is the result of a historical dynamics. Prior identification of differentiation mechanisms and trajectories may allow for effective identification of the existing production systems in a region. The use of history and mechanisms of differentiation of production systems also has the merit of identifying the "endangered" production systems and even those that have already disappeared and whose traces in the landscape, including the reading turns out to be so precious, are fading away. For this reason, the identification of production systems should be based on an analysis of the history of agriculture in the region studied (Cochet, 2005).

2.3. Data collection and analysis

Accordingly, this paper relies on literature informing on changes in the agricultural systems of the region under study and on interviews on these systems, with foci on the diversity of cropping and farming systems observed today and on the transformations in the management of natural resources, which led to these. More surveys at farm levels are being conducted. Therefore, the assessment of the strengths and weaknesses of these systems from an agroecological point of view is tentative only and proposed for discussion.

Agriculture around Bouaké has been rather extensively studied in the seventies by ORSTOM scientists. Later on CIRAD in the nineties. Now YAMSYS is also producing new evidence.

YAMSYS Participatory Rural Appraisal took place in July 2015 in the Sous-Préfecture of Tiéningboué. Interviews, both individual and in focus groups, were conducted with producers, local authorities and technical staff in Tiéningboué and with wholesalers and yam processors on the Bouaké wholesale market. The team conducted 64 interviews with the various actors in the value chain, including 47 in individual and 17 in groups. These interviews concerned both men and women. The number and types of interviews by actors are shown in Table 1.

Table 1: Number and type of interview by actor

Actors	**Focus group**				**Individual**			**Total**
	Men	**Women**	**Both**	**Total**	**Men**	**Women**	**Total**	
Farmers	5	5	3	13	28	2	30	43
Sellers	1	-	-	1	7	-	7	8
Carriers	2	-	-	2	-	-	-	2
Processors	-	-	-	-		1	1	1
Village and religious authorities	1	-	-	1	1	-	1	2
State representative (Sous-Préfet)	-	-	-	-	1	-	1	1
Agricultural extension structures	-	-	-	-	2	-	2	2
Person of interest	-	-	-	-	1	-	1	1
Other services (Inspection, health center, etc.)	-	-	-	-	3	1	4	4
TOTAL	9	5	3	17	43	4	47	64

Source: Survey data, 2015

Information collected concerned producers' and farms' socio-economic characteristics of , their yam cultivation practices, the producer's perception of its soil fertility management , the actions carried out by extension and other institutions, and the level of intervention of other actors in the yam value chain.

A second appraisal was conducted in March 2017 by a team of agroeconomists and agro sociologists. Two tools were used, interview guides specific for different groups according to their ethnical group or autochthony and to their gender nd field visits in order to visualize in situ the distribution of crops on the plot, cultivation practices and features of the landscape of each site. Seven (07) fields were visited (see Table 2).

Table 2: Interview groups formed in each locality

Interview groups	Mamouroukaha	Dabakalatou	Gbofaratou
Men Koro	+	+	
Women Koro		+	
The elderly Senoufo	+		
young Senoufo	+		
Women Senoufo + Koro	+		
Baoulé et Lobi group		+	
Senoufo et Malien group		+	
Young and elderly Lobi			+
Young and elderly Koro			+
Women Koro et Lobi			+

+ Group met in the locality

Source: data survey, 2017

2.4. An area with biophysical potentialities for yam production

The sub-prefecture of Tiéningboué (Picture 1), with geographic coordinates 8 ° 11 '60' 'N, 5 ° 43' 0 '' W is located in the north-western region of Ivory Coast. The population of Tiéningboué is 41 218 people according to the 2014 general census data and composed mainly of the indigenous Koro group. However, Senoufo from the northern Côte d'Ivoire and West African nationals from border countries also settled in this region. All these populations have yams as staple food and migrants settled down because of the possibility to grow yam in the area. In addition, there is a strong market demand for yam in this area, especially from the wholesale market Bouake, located 109 km from Tiéningboué. The agroecological zone is known as a forest-savanna transition area.

Transition areas composed of forest and savanna mosaic can be found as a horizontal belt, more or less parallel to the coast in West Africa. This ecosystem is either explained by rainfall patterns today (lower rainfall explaining the extension of savanna) or as relict of ancient processes (during the Holocene), where dried savanna replaced forest and where fire climax impeded reforestation ever since in spite of higher rainfalls. Our region is located in such an area known as the Baoule V, V because of the shape of the savanna expanding southwards in the forest.

Overall, soils and climate are rather favourable to agriculture in the area. 1000 to 1400 mm rainfalls over a 7 months vegetation period allow for a large range of crops.

Picture 1 : Location of Tiéningboué in Côte d'Ivoire

Source: www.mapsofworld.com December 30, 2014

2.5. Historical trends and changes in the landscape

Interactions between natural and cultivated vegetation are neither straightforward nor simple. Human settlements certainly reduced forest cover for cocoa (southwards) and formerly coffee farms (in Tieningboue), but at the same time, settlements in savanna also allowed to partly control bush fire and to install agroforests and nowadays cashew plantations. According to landscape studies, tree coverage would even have been improved through densification of human settlement within the savanna region through the plantation of agroforests and natural reforestation.

In transition areas where both forest and savanna ecosystems coexist in patches farmers are more inclined to use either one or the other type of ecosystem depending on the vegetation of their region of origin. According to (Blanc-Pamard, 1975), Baoule farmers for example are savanna specialists who prefer to grow yam in savanna as a first crop after clearing; yam would only be cultivated after forest as a mixed crop with a perennial crop during the set-up of the plantation. At the time of her study in the seventies, these producers would cultivate a plot for two years after fire clearing of the natural vegetation, including killing of the trees: yam was cultivated in the first year in association with many other crops and groundnut and maize in the second year. Second year crops are the women’s crops. The plot would then return to fallow for 6-12 years or become a coffee or cocoa plantation. In both cases, natural perennial regrowth would quickly invade the cultivated plot and coexist with the planted perennials until time for harvest. Somehow at that time farmers created little disturbance in the forest ecosystem and even contributed to its expansion. But how did this evolve after further changes in settlements, commoditization of agriculture and more climatic hazards.

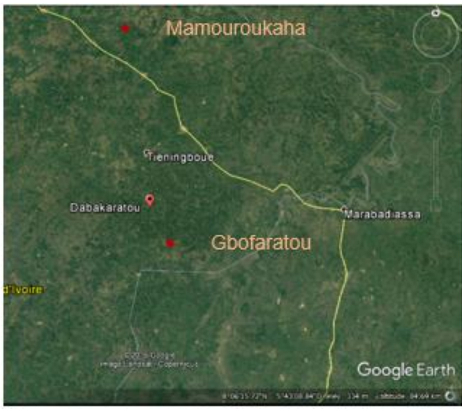
In the nineties, farms were already more diversified and could be grouped in different types including (1) traditional yam-based cropping and farming systems, (2) perennial farms (cashew, coffee and palms), (3) high market value crops systems (early yam being one of them) and (4) cotton-based systems for new settlers (Dugué et al. (2000); (Dugué et al., 2003). Changes could be explained by migrations and market development on one hand, by changes in land pressure and land rights on the other hand. Bouaké wholesale market was constructed in 1998 and became a major exchange place for the yam regional trade in West Africa.

In the 70-90ties, Baoule farmers massively moved southwards towards the cocoa belt until no more land was available. Both Lobi and Senoufo farmers migrated from the North into our area, Lobis because of their need of fertile land for yam and Senoufo, because of their need for large farms where cotton could be cultivated. Expansion of cashew plantations were already visible among autochthonous farmers who also expanded their yam fields, yam becoming a cash crop. First settlers therefore began to impose strong land expansion and use limitations to new settlers, who started cultivating in sedentary systems without any natural fallow and without tree crops.

In this reference study during the RRA in 2015, 16 villages were covered

Then three localities (cf Picture 2) were selected for the case studies: Dabakalatou, Mamouroukaha, Gbofaratou, located respectively 7km, 20 km, and 17 km from the town of Tiéningboué. Dabakalatou is a relatively large village funded by the autochthonous Koro population, who then attracted migrants, who work for them (Baoule, Senoufo, Malians, Lobi). Mamouroukaha is a large Senoufo village created in 1989 when a migrant asked for land by Koro landlords and let many other settlers come, until they built a larg village. Gbofaratou is a “campement”, initially meant as a temporary settlement for Lobi migrants installed by Koros in order to tend their land.

The landscape (Pictures 3 and 4) shows forests / fallows or small savannas, cashew plantations, seasonal crop fields. The rice-growing areas are quite numerous. The vegetation consists of residual forest islands with three floors (coppice, intermediate trees and large trees). There are usually no trees in fields grown outside cashew trees.



Source: Google Earth, date of satellite images on 05/02/2017

Picture 3 : Spatial distribution of the three localities visited

Picture 4 : Mamouroukaha Landscape

3. RESULTS

3.1. Yam as a major component in cropping systems

Differences observed between ethnic groups in the past are still influencing their cropping systems nowadays. Senoufo producers still grow cotton as a leading crop (2-8 ha) and followed by maize and rely on its inputs for the cropping system fertility management and its cash for the farm management. Elder Senoufo settlers planted cashew but nowadays they are restricted in their progression. Their plantation covers 2,5 to 9 ha while Koro plantations can reach 20 ha cashew. Both groups cultivate rice (up to 3 ha), yam (up to 3 ha) and groundnut (less than one hectare).

In these different localities, cropping systems (Table 3) are based on rotations with annual crops (yam, cotton, rice, groundnuts) and perennial crop (cashew). Rotations differ among ethnic groups. Moreover, cotton farming appears as a discriminating criterion in the production system:

- Among the Koro, who are the first settlers and prefer forest land, yam comes after fallow followed by rice and/or groundnut, followed by maize after which land may return to fallow or yam may come at least a second time. Maize stalks will be used as stakes and it may have been fertilized. After a 2nd or even a 3rd yam, the same succession of rice or groundnut and maize takes place and the land is returned to fallow. Koro farmers prefer cultivating the labour- and fertility less demanding D. alata, especially the *Betebete* variety, which is easy to store.
- Among the Senoufo, who prefer savanna land, similar successions are observed but cotton is cultivated after the second yam crop to replenish soil nutrients stocks. They prefer D. rotundata, especially the *Krenglé* variety. Fallow is short (2-3 years) and Chromolaena odorata as a pioneer specie in forest succession is well appreciated as a previous vegetation to be cleared for yam.
- Lobis prefer cultivating yam after fallow, they have early yam as a specialty and it is a demanding crop.
- Yam may also be intercropped with cashew. Rotations are then interrupted when the tree cover hampers annual crop development.

Table 3 : Main crop rotation of the most represented ethnic groups in each locality.

<table>
<tr><th></th><th>Dabakalatou
(Koro dominant + migrant groups)</th><th>Mamouroukaha (Senoufo)</th><th>Gbofaratou
(Lobi migrants and few Koro landlords)</th></tr>
<tr><td>Koro</td><td>Fallow-yam—rice / maize/groundnut -yam ...</td><td>Yam—rice—yam—rice—yam—maize/cotton—yam—rice—….until fallow</td><td>Fallow— (yam+cashew) —groundnut—rice—maize—yam—cashew</td></tr>
<tr><td>Sénoufo</td><td>Fallow—yam—rice or maize or groundnut—yam—rice or maize or groundnut.</td><td>yam/cotton or rice/ groundnut/ maize or yam/ cotton-rice</td><td></td></tr>
<tr><td>Baoulé</td><td rowspan="2">Yam+cashew—groundnut+cashew—rice+ cashew—yam+cashew—cashew</td><td></td><td></td></tr>
<tr><td>Lobi</td><td></td><td>fallow—yam—groundnut— yam or maize— groundnut or maize—fallow</td></tr>
<tr><td>Maliens</td><td>Fallow—yam—rice or maize or groundnut—yam— rice or maize or groundnut.</td><td></td><td></td></tr>
</table>

— Rotation (next crop); **/** rotation.; **+** cultural association; **or** alternative crop on the same plot

Many autochthonous farmers now cultivate yam intercropped with cashew. Therefore the length of the rotation is determined by the development of the tree canopy (no more than three cycles with yam). Some of the elder settlements of migrants are also authorised to plant cashew trees. New migrants and labourers are not.

Biomass and soil fertility management

When clearing a plot, biomass is burnt. Trees also are killed by setting their base on fire. Very few may remain and are used as stakes. “*If you burn the plot and the soil is black, yam with thrive*”. Within rotations, different versions of what can be buried and what should be burnt coexist among farmers. Rice straw may be incorporated in the soil, especially in yam mounds, while groundnut foliage may be burnt. Farmers are more knowledgeable about fallow composition and length than about rotations and biomass management.

Current management of soil fertility is not biomass-saving. Either knowledge about biomass management in more intensified cropping system is not stabilized and practices from times of too abundant biomass are still prevailing, or there are some other reasons for biomass systematic burning, such as labour saving.

Very few producers use mineral fertilisers on yam crops. Cotton producers who have an easy access to it, use it rather on the preceding crops. They expect fertilisers to negatively alter the organoleptic properties of the crop and its storability.

Many phenomena and behaviours are associated by producers to yam yield decrease on a plot, resulting in sets of rules such as not entering a yam field with shoes. This reinforce our opinion that producers cannot link the observed yam productivity decrease with its complex bundle of causation factors.

Picture 5: Fire clearing of a new field in Mamouroukaha
Source: Field data, March 2017

Cultivated biodiversity

Blanc Pamard (op. cit.) mentioned 18 Dioscorea species and around 50 yam varieties in the seventies. Discorea alata and Dioscorea cayenensis were both sorted in two groups (Bété-Bété and Nza; Lokpa et Krenglé). Varieties prefered either savanna or forest environment.

Our own survey in Tieningboue counted 8 yam varieties in the area, 6 D. alata and 2 D. rotundata. D. rotundata cultivated varieties (krengle and kougbe) produce early yam with a high market value but are also labour- and skill-demanding. The first harvest has to be performed with care to allow for a second harvest of smaller tubers used as seeds. In a plot, varieties are planted in blocks, and not mixed up. It makes management easier and prevent varieties with thorny vines to wound other varieties. Yam is cultivated in mixed cropping, in particulier with vegetable crops (tomatoes, chilly pepper, eggplants, etc.) and cassava, and also intercropped with cashew trees when the intention is to turn the plot into a plantation.

Pest management

According to farmers, yam varieties would rapidly degenerate and lose their performance and organoleptic aptitudes. Indeed, reproduction being vegetative, virus and other diseases can affect seeds. Not all farmers recognize mealy bugs or nematodes as a pest either and not all farmers sort infected yam seeds out.

Our hypothesis is that a high concentration on very few marketable varieties correlated with difficulties in obtaining healthy seeds when yam is cultivated several times on the same plots and when fallow becomes shorter, means that most varieties might disappear.

Weeds management

Yam is sensitive to competition and farmers are used to weed 3 to 5 times a year. They make an increasing use of herbicides: total herbicide (glyphosate) for the land cleaning before mould construction and more selective herbicides just prior to yam emergence. They can’t find selective herbicide for later stages, therefore weed with the hoe.

Staking yam vines is a yield enhancing technique. Some varieties are more susceptible to it than others. Weeding and intercropping of staked yam is easier. However, some farmers who need to save time do not stake because of the weed smothering effect of the vines when spreading over the soil.

In all, labour-saving practices may be preferred by farmers at the cost of the yam yields. Elder farmers complain that younger ones do not manage their yam fields with sufficient care and prefer expanding the area rather than providing optimal care on a small area.

Income and food availability and stability

Most producers say they suffer from food shortages in July and August, when no more yam is available. Yam is not easy too store. Albeit producers do build straw huts, mould losses may be up to 20 to 40% of the harvest. In the Senoufo village, producers complained that their D. rotundata was losing its storage ability on some fields but not on others. They could not explain this phenomenon. A large share of the harvest has also to be kept as seed for the next year (20-30%).

Elder settlements, especially autochthonous and elder migrants, have better housings and livelihoods than new migrant hamlets. Elder migrants came in time of land abundance and labour scarcity and they were granted land rights for little obligations towards their "tutors" and no restrictions on plantations. Nowadays, in the Koro village of Dabakaratou for example, migrants from Mali come in search of work and may ask for a field. They then have to maintain the tutor's cashew plantation, which they intercrop in and should give a rent in kind; if they have been authorised to plant their own cashew, they have to share their harvest in proportion of 1 to 1 with their "tutor". On plots where they intercrop in the tutor's cashew, their rights have a limited duration: as soon as the tree canopy covers the soil, they have to ask for another plot. New migrants have a low room for manoeuvre and no incentives to develop sustainable agroecological practices. Nevertheless, they craft some new opportunities for themselves, such as ginger cultivation, which requires little space and cultivate early yam also, which has a high value per land unit.

As land becomes scarce and migrations for labour abundant, autochthonous tutors can even restrict the expansion willingness of elder migrant groups in expanding their own farms with the help of contracted seasonal workers from elsewhere, rather than employing the local allochthonous youth.

In all, income stability is an issue for new settlers more than for elder ones, would could build a living in times of abundant land and natural resources.

Social autonomy and knowledge exchange among yam producers at Tiéningboué

Yam has been neglected by research and extension. The few technologies developed by research, on seed multiplication and storage or on the use of cover crops and planted fallow are not known by producers. Producers had to rely on their own social networks to access to valuable information or adjust information obtain through cotton networks. Cotton marketing boards and recently a cashew marketing society work with cotton farmers and provide them with technical extension. As discussed above, in a rapidly changing environment, farmers' knowledge and skills are more and more challenged as they fit better with the adequate choice of fallow land than with the management of plots under permanent cultivation.

Main stakeholders, producers engage with, are traders and their commissioners ("pisteurs"). In the larger of the three villages investigated, there were 6 or 7 of these intermediaries. They are well informed about market demand and prices but may not be so eager to pass this information to farmers. Credit on a future yam harvest obtained by farmers from traders is also not uncommon. In both case information is asymmetric.

Among the Koro, land is managed by a land chief. Customary authorities such land chiefs and village chiefs interact with their village committees for conflict resolution, including land conflicts. Such issue may concern access rights to farmland, land settlement conflicts,

conflicts between farmers and livestock keepers, protection of natural resources (water and forest) or yam marketing conflicts. Institutions exist which can regulate internal issues at village level.

In this context of unequal internal relationships and a lack of external linkages, a major task of the Yamsys project was to initiate a multi-stakeholder platform to bring these actors together in order to reflect on yam problems.

Social autonomy and the ability to ensure an asset base for the next generation

By looking at landscape pictures from Google Earth it appears clearly that very little forest land in left for new settlers. Most the land is now farmland either cultivated with annual or perennial crops. Koro and Senoufo households are large, multigenerational and everybody works on the farm under the authority of the farm household heads. Young people may not even cultivate plots on their own or when authorised a yam plot. However, when the household becomes too large, farmland is not available on or nearby the farm, and harvests do not cover the household needs anymore, elder sons may ultimately be sent elsewhere to look for new land. What will happen when not more new land can be taken into cultivation, which already the case by the Lobi settlers in our third study case. Helping a son to develop a farm on his own by giving land is nearby impossible for the household heads, putting the intergenerational pact at risk.

Land scarcity is affecting women in the first place. Koro women cultivate on plots already cleared by male farmers – in the year following yam harvest, they grow groundnut, maize, chili pepper and yam. They may also be granted plots in cashew young plantation, which maintains the plantation. Cultivation in the second year after yam is a traditional right, which women have on the land. They then should not ask for money for “condiments” when preparing food. Lobi women in the opposite are not given any plot. They intercrop their vegetables and cassava within the husband’s crops. Husbands do not have enough land and won’t grant a plot to their household female members.

3.2. Weaknesses and threats to the development of agroecology

As a result, practices are very diverse and unstable from one community to another and within the same community. This leads to different cropping systems. Criteria explaining this variability are farmers’ autochthony, seniority of the settlement and agreements between landlords and farmers, land availability, sex of the farmer and access to cotton inputs. There are also many practical rules which producers are developing now in response to a changing environment, which may or may not be very appropriate for an agroecological management. Table 4 summarizes major findings of this diagnostic stage in the research, opening new questions for the next stage.

Table 4: Strengths and weaknesses in the cropping and production systems

	Strengths	Weaknesses and threats
Landscape management	Cashew plantation contributes to a forest like cover and to run off and erosion control	Expansion of plantation increases the intensification pressure on the rest of the land Cashew does not tolerate association with other tree species and smother them Differentiated management along the catena (up and lowlands)
Soil management	Good knowledge about natural vegetation attesting that the soil is regenerated for yam	Little skills on managing preceding crops for soil improvement Biomass burnt rather than incorporated Unstable understanding of which crop is a good preceding crop for yam
Pests and weeds management		Seed health management inadequate Systematic use of herbicides twice per year in all crops
Biodiversity maintenance	Good knowledge of a range of yam varieties Introduction of a few varieties (mostly D. alata) through research and by immigrants Wild yam protected in cashew plantations	Degenerescence of seeds Probable loss of yam varieties Probable specialisation on 2 varieties preferred on the market Access to seed is difficult (no market)
Ssusceptibility to intra & interannual variations	Tuber and tree crops less susceptible to climatic variability than cereals	Rather low diversity of crops compared to the agroclimatic potential
Local knowledge preservation & enhancement	Cultural mix with a large diversity of ethnic constellations Slowly growing interest for the on-farm trials and yam platform activities	No extension activities on yam Very little research Migrants take over their tutors farming practices without hybridising with their own
Social autonomy: agreements conducive to sustainable resource	Traditional land rights were very flexible in times of land availability	New land rights impedes any investment in land
Social market autonomy	High demand for yam on the markets	Dependency on brokers' market knowledge Sometimes credit from traders and yam sale at low price Lack of producers' organisation for sale in bulk and negotiation
Asset base and aptitudes to cope with crisis	Cashew has a stabilising function on income (?)	Difficult for new migrants to make a living there. Today migration is to earn money and go elsewhere or back to the place of origin.

Based on the five (5) principles of agroecological development enunciated by Altieri, the weaknesses identified in Tiéningboué are at several levels. In local production practice, there is usually a low biomass and nutrients recycling in spite of a reduction in the fallow length. Besides this, diversification of crops and varieties is low and may be hampered by the colonization of area by cashew trees.

In addition, there are socio-technical barriers that may hamper a transition to new agroecological practices. In fact, at the individual level, the producers are in deficit of knowledge on new agricultural practices.

3.3. Perspectives of adaptive management towards agroecology: advantages, opportunities of the local system

Production systems in Tiéningboué offer some agroecological potential within the scope of family farming. Some local practices are geared towards increasing biodiversity by avoiding monocultures that require inputs of pesticides and fertilizers. This includes the use of long rotations and associated crops (Marsden et al., 2017), which make it possible to benefit from the facilitation or complementarity of ecological niches of different species (cereal-legume associations). For Tiéningboué, rotations in terms of succession of culture and duration are appropriate. Yam after maize is thrifty because the stalks of corn (Zea mays) can serve as stakes.

Natural fallow could be managed by assisted natural regeneration in a way where its regrowth after 2 or 3 crop cycles replenishes the soil at a quicker pace. This requires selective management of the natural vegetation instead of its indiscriminate removal by fire. Fertilization and weed control in rotations could be improved using cover crops, green manures and compost. The goal is to maintain a high humus level that ensures sustainable fertility and ensures a more regular water supply on one hand, to reduce the use of herbicides in replacing them by smothering crops. These means require little cash (but some additional labour) and may be accessible to poor farmers. Dung from animals in the area, poultry and livestock available is not used, not even by farmers using animal traction. In all several pathways may reduce nutrients losses and improve recycling and entries in cropping systems as well as smart transfers at landscape levels. They may need participatory research and the design of equipment to reduce their labour demand and hardship. Integrated pest and disease management can also be developed with local knowledge to minimize chemical control.

Traditional know-how is therefore an asset to tap to ensure ecological and economical management of farms. Agroecological knowledge may be produced for example through tests carried out with producers in a participative learning process.

4. Conclusion

Agroecology appears as a tool for rural development as well as for revitalizing soils cultivated with pesticides. Indeed, it is an alternative of choice to production systems with a focus on the sustainable balance of the soil-crop system. It allows for a reduction in input inputs over the long term. Taking into account this equilibrium also leads to better resistance of crops to difficult conditions such as weed pressure and depleted soils. And this fits into the objectives of the Yamsys project.

This study reveals that even though agroecological practices are not common in the Tiéningboué area, the latter is full of potentialities for adaptive management options within the yam grower's reach. Few practices are already following the trajectory of agroecology. This is how the Yamsys project set up two approaches. On the one hand, soil fertility management technologies are developed by researchers in mother trials and followed by a test in a diversity of farm environments through farmer-managed baby trials. On the other hand, an organizational innovation is the innovation platform composed of either direct or indirect actors in the yam value chain.

Because yam is important for food security and the food system of this territory, the sustainability of production systems would be more assured with agroecological practices that offer management and maintenance of natural resource performance. And this involves the involvement of the key stakeholders identified.

Thus, the Yamysy project is highlighting the biophysical, institutional and economic and environmental determinants at the yam level that can be presented to decision-makers for agricultural policies in favour of this speculation, which has the potential not only to contribute to food security but also to provide incomes along the value chain in a sustainable way.

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