Political Ecology in the Oil Palm-Based Cropping System on the Adja plateau in Benin:

Connecting Soil Fertility and Land Tenure

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Abstract

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On the Adja plateau (West Benin), multiple actors are involved in an intercropping system with oil palm and food crops. This system is known as the oil palm-based cropping system (OPBCS). It contains two stages: a stage of small oil palms underneath which food crops are grown and a fallow stage with mature oil palm. Landowners grow oil palm mainly for the artisanal production of palm wine and *sodabi*, rather than for palm oil, for which the region is unsuitable for climatological reasons. The OPBCS has to be analysed not only from a technical and ecological perspective, but also from an institutional one. In the OPBCS there are competing claims between landowners and tenants for land use. Tenants access land under specific customary rules, grow food crops beneath oil palm and extend the cropping period by severely pruning palms because their right to grow food crops terminates when the palms reach a height of 2 m. Landowners claim that extended cropping reduces soil fertility and that long-duration oil palm fallows are necessary for soil fertility regeneration. Tenants state that long-duration fallow maintains land scarcity. In an attempt to remedy the competing claims, a land titling programme was implemented in some villages on the Adja plateau.

I analysed the system with a political ecology lens. I demonstrated the implications of the multiple institutions for land access and ownership, and therefore for the competing claims. Land titling initially created land insecurity for tenants, as they were thrown off the land by owners who wanted to demonstrate ownership. Subsequently, new rules related to land access by tenants were introduced. Both ownership and access by tenants relied on a different mix of formal and informal practices, as evidenced by formal contracts, *petits papiers* and a new paper contract. The new paper contract provides tenants the rights to rent the land for up to 25 years. The titling programme also enhanced on-going processes of intensification and commercialisation, as evidenced by increased use of mineral fertiliser and the regression of the OPBCS. The long-duration fallow periods did not improve biological and chemical soil fertility. Long-duration fallows are rather used as an expression of control over land. Mineral fertiliser and organic amendments (household waste) explain lack of effects of fallowing. Application of household waste and mineral fertiliser did not change soil organic matter content. Organic amendments increased maize yields more than mineral fertiliser. Household waste did not improve agronomic use efficiency of mineral fertiliser.

I suggest that formal and customary land tenure institutions can be blended to generate a hybrid system. Such a hybrid system might contribute to sustainable soil fertility management.

Keywords: Innovation system, Soil fertility management, Land reform, Participatory technology development, Social change, Agroforestry, Land access rights, Fallow, Agricultural intensification, Africa

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Rolland Yemadje
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List of Acronyms

AM	Arbuscular Mycorrhiza
ANOVA	Analysis of Variance
CoGeF	Comité de gestion foncière
EC	Mineral fertiliser
FAO	Food and Agriculture Organization
FCFA	Communauté Financière Africaine
FGDs	Focus group discussions
GRAIB	Groupe de Recherche et d'Appui aux Initiatives de Base pour un Développement Durable
INRAB	Centre de Recherche d'Agonkanmey, Institut National de Recherches Agronomiques du Benin
KTI	Knowledge, Technology and Innovation
LSSEE	Laboratoire des Sciences du Sol, Eau et Environnement
LUT	land use type
MCA	Millennium Challenge Account
NPK	Nitrogen Phosphorus Potassium
OM	Organic matter
OPBCS	Oil Palm Based Cropping System
OPBCS	oil palm based cropping system
PFR	Plan Foncier Rural
PGRN	*Programme de Gestion des Ressources Naturelles*
PGTRN	Programme de Gestion des Terroirs et Resources Naturelles
SCGFA	Sous-commission de gestion foncière d'arrondissement
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SSA	Sub Saharan Africa
SVGF	Section Villageoise de Gestion Foncière
US	United States of America
USDA	United States Department of Agriculture

Chapter 1

General Introduction

1.1 Introduction: Setting the scene

Agricultural intensification demands food production technology investment as well as institutional reconfiguration. Sustainable food production needs sustainable soil fertility management (Giller *et al.*, 2011) as well as land tenure security (Maxwell and Wiebe, 1999). However, throughout African societies, customary land access has not always seemed to provide the best guarantee for allowing investments in soil fertility. In response, solutions have been proposed for land tenure management, based on the argument that management of land as an open access resource (*commons*) is at risk of resource mining (Hardin, 1998). At the same time, formal responses to individualise land tenure did not always lead to equitable tenure arrangements, nor did they always meet the key assumption of the neoliberal interventionists that individualisation of land tenure encourages agricultural investments (Platteau, 1996).

This debate between proponents and opponents of Hardin-based solutions draws attention to both technology development and complex social and institutional settings in order to meet the challenge of feeding more than 9 billion people. Succeeding in this challenge by socially and ecologically sustainable means demands intensifying methods of cultivation. Agricultural intensification has been defined in many ways, including: decreasing the yield gap, increasing cropping intensity per unit of land, and using high-value crops (Pretty, 2013). This definition overlaps more or less with (Boserup, 1965) definition of agricultural intensification as a gradual change towards a pattern of land use that makes it possible to crop a given area of land more frequently than before. Often these land use practices demand an increase in fertiliser use. (Tittonell and Giller, 2013) linked agricultural intensification in sub-Saharan Africa (SSA) with ecological intensification, which they described as an increased use of organic matter.

1.1.1 The challenge of agricultural intensification in sub-Saharan Africa

The challenge of feeding more than 9 billion people in 2050 is of worldwide concern. In SSA, meeting that challenge requires changing methods of cultivation, soil fertility management and land access practices that are different from those of the last century (Godfray *et al.*, 2010). Tittonell and Giller (2013) studied the relation between fertiliser use and cereal yields, and noted a widening of the yield gap between examples countries in the North and in the South. In Europe, both fertiliser use and cereal yields increased until 1973; after that date yields continued to grow in spite of stagnating (1974-1989) and then declining (1990-2008) fertiliser use. In China, the US and Brazil cereal yield increases correlated with growing fertiliser use. In Kenya too, fertiliser use grew between 1960 and 2005, but cereal yields responded less strongly to fertiliser and stagnated since 1995 in spite of the fact that fertiliser use further increased. In Burkina Faso, both fertiliser use and cereal yields grew until

1996, and yields continued to grow after that in spite of highly fluctuating fertiliser use. The data from Tittonell and Giller (2013) further suggest that yield response to fertiliser was stronger in China than in Brazil and the two African countries, which suggests that yields in Kenya and Burkina Faso either approach potential yields or are constrained by other factors. In summary, these data indicate that fertiliser may contribute to cereal yields but that yields depend on more than fertiliser use alone. Other factors may relate to technology development and to complex social and institutional settings in which cereal production is embedded (Blaikie and Brookfield, 1987).

Local knowledge has long been an important driver for technology development for agricultural intensification in Africa (Richards, 1985). Along with (Giller *et al.*, 2008), I call for the replacement of a one-dimensional approach to agricultural intensification, as top-down application of scientific knowledge, technology and policy intervention (Hounkonnou *et al.*, 2012), by a pluralistic socio-technical understanding, which has implication for research and practice in SSA.

1.1.2 The challenge of soil fertility management

Many soils in sub-Saharan Africa have intrinsically low soil fertility. Furthermore soil nutrients are often not replaced adequately. However, this statement mainly applies to outfields (fields at some distance from the village) and to upperslope fields (Kagabo *et al.*, 2013), and much less to home fields that are much more likely to receive organic amendments and sometimes also mineral fertilisers. The most obvious solution to nutrient depletion is external input of nutrients in the form of mineral fertiliser. While mineral fertiliser restores chemical soil quality (soil fertility), its contribution to biological and physical soil quality is more contentious.

Approaches to manage/maintain soil fertility at acceptable levels have often been formulated within a cropping system paradigm following nutrient balance models (listing inputs and outputs). The solutions developed attempted to remedy the lack of nitrogen via mineral fertiliser application and the use of nitrogen-fixing legumes. Phosphorus and potassium fertilisers have also been advocated, whereas correction of micronutrient deficiencies (zinc, copper, iron) occurs infrequently. However, the agronomic efficiency with which these fertilisers are used by plants is variable and depends on the amounts of organic matter (Bationo and Buerkert, 2001). Soils that are (too) low in organic matter show a low agronomic use efficiency of mineral fertiliser; such soils have been classified as non-responsive (Vanlauwe *et al.*, 2010). Organic matter and soil biological activity have long been described as partly responsible for soil fertility (FAO, 2003). The extent to which this applies varies between soil types. Organic matter addition can regenerate non-responsive soils (Vanlauwe *et al.*, 2011).

In humid and semi-humid Africa, the dominant cropping systems are characterised by the presence of maize (*Zea mays*), cassava (*Manihot esculenta*), groundnut (*Arachis hypogaea*), and cowpea (*Vigna unguiculata*) (Houngbo *et al.*, 2008). In former times, a few years of cropping were alternated with long fallows for soil fertility regeneration and suppression of pests and weeds. Often crops were grown in complex spatio-temporal arrangements such as intercropping or crop rotation. With increasing pressure on land, mixed cropping has often been replaced by cereal monocropping. Fallow length has been reduced to the point that lands are now cropped almost continuously. Farmers have also developed soil management practices based on extensive cropping such as cassava fallow (*jachère manioc* (Saïdou *et al.*, 2008)) and oil palm fallow (*jachère palmier* (Brouwers, 1993)). African farmers' adoption of organic amendments for maintaining and restoring soil fertility is quite mixed (Honlonkou, 1994). The high costs and low availability of mineral fertiliser make farmers sometimes organic farmers by default, relying only on organic amendments that are often incorporated into the soil with the ridging practice.

Ridging is a cultural practice associated with ethnic groups from the North and North-east immigrants in Wenchi, Ghana (Adjei-Nsiah *et al.*, 2004), Fon on the Adja and Allada plateaus, Benin. Farmers in the forest-savannah transition zone, where 'traditionally' ridging has not been a default practice (this in contrast with West African savannah zones where it is default) are convinced that ridging raises yields, at least in the short run (Azontonde, 1993, Wartena, 2006). The ridging practice is a soil fertility management strategy to raise yields without necessarily raising the overall fertility of the soil (perhaps even through mining it). The few 'hard' scientific studies that exist on ridging do not show a long-term soil fertility restoration property (Azontonde, 1993).

1.2 Enhancing soil fertility for agricultural intensification

Organic matter is a key component for enhancing soil fertility for agricultural intensification. The involvement of mineral fertiliser use as component of this soil fertility is constrained by farmers' low incomes in SSA. Moreover, the state of the roads, the difficulty to manage the logistics and many other institutional aspects do not facilitate the use of mineral fertilisers (Tittonell, 2013). However, in SSA, application of organic amendments may be constrained by labour availability. For example, the application of household waste on the Adja plateau fields in Benin requires high levels of labour inputs (Wartena 2006: 44-45). Including all these other factors, agricultural intensification effectively demands investment in the combination of mineral and organic fertiliser.

Organic matter application could be a useful complement to enhance soil fertility in the SSA rather being an alternative to mineral fertiliser. Beyond the technical considerations of soil management, the social dynamics of land tenure institutions also affect agricultural intensification in SSA (Lawry *et al.*, 1994, Blume, 1998, Quisumbing *et al.*, 2001, Adjei-

Nsiah *et al.*, 2004, Saïdou *et al.*, 2007, Clover and Eriksen, 2009, Oladele *et al.*, 2011) as I will discuss below.

1.3 Multiple land tenure institutions

1.3.1 The concepts of institution and institutional bricolage

Neo-institutionalists like (North, 1991) and (Lowndes, 2002) define institutions as rules of the game guiding social interactions to reduce uncertainty and ambiguity. (Cleaver, 2002) distinguished between bureaucratic and socially-embedded institutions. Bureaucratic institutions are based on formalised arrangements based on clearly defined organisational structures, contracts, legal rights and introduced by governments or development agencies (Katani, 2010). Socially embedded institutions are those institutions based on culture, social organisation and daily practices, commonly referred to as customary. Often, both kinds of institutions co-occur in SSA. The coexistence of plural institutions has been coined as legal pluralism (Benda-Beckmann von, 2002). Cleaver (2002) opposed her definition to that of North while emphasising the positive role that ambiguity under multiple institutions could play in shaping institutions. Actors in formal and customary institutions have a key role in shaping them, especially when institutional processes mix both formal and customary components. That process has been coined as *bricolage* (Cleaver, 2002). Institutional *bricolage* refers to a patchwork of different institutions or also new (hybrid) institutions that emerge after the juxtaposing, reshaping, disassembling and reassembling of formal and customary institutions. The concept was originally introduced by Lévi-Strauss and subsequently adapted by Douglas (Cleaver 2002). The *bricoleur* uses whatever is available to accomplish a task at hand without a priori set of ideas of how to use them (Katani, 2010: 14). My thesis uses the concept of *bricolage* to analyse the process of institutional change, recognising the agency of individual actors with sometimes opposing interests. Cleaver (2002) defined institutional bricolage at local level without mentioning whether it is applicable to analyse social processes at higher-than local levels, i.e. land tenure security formalisation (Katani, 2010).

1.3.2 Tenure security and soil fertility management

Tenure security is the reasonable guarantee of land rights, supported by the certainty that one's rights will be recognised by others and protected by legal and social remedies (Knight, 2010).

Some authors discussed tenure security in sustainable agriculture (Pandey *et al.*, 2001) and soil fertility management (Adjei-Nsiah *et al.*, 2004, Saïdou *et al.*, 2007). Lawry *et al.* (1994) recognised the implication of land tenure security in alley-cropping adoption in Cameroun, Togo, and Nigeria. These latter authors noted existence of unequal power between different actors in land tenure practice, resulting in land access and arrangements that

excluded the weaker group. Power shapes human-environment relationships (Lawhon and Murphy, 2012). Moreover, power manifests not only in the ability to control or dominate others, but as a medium to achieve environmental or political goals (Allen, 2003). For that reason, powerful actors are often unwilling to change the rules of the game unless the new rules can result in a win-win situation for all actors. In the Save region of Benin, land tenure arrangements were identified as a main factor for soil fertility decline (Saïdou *et al.*, 2004) as well as in the Wenchi region of Ghana. In both regions, powerful native and weaker migrant communities were captured in practices that had negative consequences for soil fertility. The migrants could only access land through short-term tenancy arrangements, which discouraged them from investing in the soil (Adjei-Nsiah *et al.*, 2004). However, the debate is not only opposing migrants and natives, but is also opposing powerful landowners and weaker tenants. Both perspectives bring the importance of land access and ownership rights to the fore.

1.3.3 Land tenure formalisation in SSA

The debate on land tenure formalisation is characterised by two opposing positions. On the one hand, several authors emphasise the potential of social capital and customary systems (Platteau, 2000, Delville *et al.*, 2002, Obeng-Odoom, 2012), whereas others adhere to a neo-liberal individualist theory (Hardin, 1998, Soto de, 2000a). Government land policies backed up by the World Bank under the structural adjustment programs (SAP) often subscribed to the latter view. However, that latter position has received increasing criticism. The roots for the neo-liberal model can be found in what has been called the evolutionary theory of land rights (Platteau, 1996), where customary communal tenure is (inevitably) transformed into formal individual tenure. The underlying assumption proposes a dynamic picture in which indigenous land rights, under market impulses and a central role in/for formalisation by the government, evolve in a beneficial direction (Platteau, 1996).

However, Platteau (1996, 2000) criticised the assumption of that evolutionary theory, citing (Atwood, 1990), who observed that ‘registration can create rather than reduce uncertainty and conflict over land rights’. Moreover, Platteau stated that a significant relationship between titling and agricultural investment does not allow us to conclude *a priori* that causality runs from titling to enhanced agricultural investment. A World Bank study found that in Ghana and Rwanda an increase in individualised land rights did not have any effect on agricultural investment and yields, while in Kenya the possession of land titles was not significantly related to these two variables either (Bassett and Jacobs, 1997, Place and Migot-Adholla, 1998). There is good evidence that indigenous arrangements provide good security (Platteau 1996, 2000; Bassett and Jacobs 1997; Place and Migot-Adholla, 1998). This evidence suggest that it is important to empirically investigate how land formalisation in SSA, operating in a patchwork of legal pluralism, affects tenure security (Benjaminsen *et al.*, 2008), soil fertility management, and agricultural intensification.

1.4 Political ecology

I advocate here that agro-ecological changes in the form of agricultural intensification inside the African cropping systems need to be analysed from a pluralistic institutional perspective (Meinzen-Dick and Pradhan, 2001). I assume that power differences and social relations obstruct the actualisation of rights, especially for low-status groups (Meinzen-Dick and Pradhan, 2001). Therefore, I use the theory of political ecology to analyse local ecological changes as influenced by the larger scale social, political, and economic forces acting on local land use decision-making (Steinberg, 1998).

Political ecology emerged from the realisation that understanding local ecological changes requires the study of the influences of larger scale social, political, and economic forces on local land use decision-making (Moore, 1996). Political ecology is defined as "combining the concerns of ecology and a broadly defined political economy" with emphasis given to the "constantly shifting dialectic between society and land-based resources, classes and groups" (Blaikie and Brookfield, 1987).

Common elements of the political ecology approach are (1) an emphasis on the influence of state intervention in rural economies on land-use patterns. This is captured in this work through the analysis of the effects of the state-led interventions on changes in the cropping system in the area. Moreover, state interventions could be hypothesised as influencing the land use pattern and therefore the rural economy when lands become a sort of commodity on the land market. (2) a focus at the local level on differential responses of decision-making units to changing social relations of production and exchange. This has been accessed by analysing cropping practices (both socially and technically) inside groups of farmers and their diversity of land use pattern.

In addition, political ecology theorists are interested by issues of accumulation (Le Billon, 2001), access (Greiner, 2013), and actors (Lund and Boone, 2013). For the above-mentioned reasons, this theory enriches the analysis of cropping systems in SSA. Political ecology provides a great perspective in examining the interrelationships between local patterns of soil and crop management as affected by the larger land tenure context of the study area.

1.5 Technography methodology

Technography is the study of technique, the human capacity to pursue goals through the combination of technical and social skills (Jansen and Vellema, 2011). Both technography and political ecology grapple with interactions between social processes and the biophysical world, but where political ecology often emphasizes the social dynamics of power and contestation, technography emphasizes the social dynamics of creativity and cooperation. Because the management of soils and the practice of land tenure involve both power and creativity, contestation and cooperation, this study has elected to combine technography with

political ecology in order to analyse farmers' soil and crop management practices in the oil palm-based cropping system (referred to as OPBCS from here henceforth) (Fig.1.1). As the OPBCS evolves in response to numerous drivers, its process is shaped by changing knowledge and by socio-technical factors. This thesis analyses the relationship between the actors and their technical practices and how they are affected by changes in land tenure institutions. Technography is particularly useful because it enables a holistic view that encompasses and integrates social organization and biophysical materiality through research on the use and impact of technologies in concrete social situations (Jansen and Vellema, 2011).

Drawing on realist evaluation (Pawson and Tilley, 2001), technography provides a methodological lens through which to analyse change by understanding the relationship between contexts, mechanisms of change and observable outcomes. Both contexts and mechanisms shape the outcomes – anticipated, intended or otherwise – of events and interventions. The goal of using a technographic approach in this thesis, in combination with political ecology, is to move beyond simple descriptive research into more robust explanatory research that explores the interlinkages between soil quality, soil fertility management, owner-tenant relations and changing land tenure rules in the OPBCS on Benin's Adja plateau.

1.6 Study area

This study started after an exploratory study carried out in 2009 in the oil palm belt in Benin (Vissoh *et al.*, 2010). The entry point of that exploratory study was the oil palm-based cropping system (Wartena, 2006) on the Adja plateau in south-western Benin. After the exploratory phase, I was introduced in the Adja plateau community. In Benin, oil palm (*Elaeis guineensis*) is gaining higher importance, next to cotton as major export crop (Sinzogan *et al.*, 2004). Developing the oil palm sector (the chain from production to processing and marketing of palm oil) is one of the national priorities of Benin. In order to yield large amounts of oil, oil palm tree needs sufficient rainfall. Under more marginal ecological conditions, such as in the south-western part of Benin (Adja Plateau), oil palm is grown, but it serves other purposes such as alcohol production (*sodabi*, a local spirit). The primary interest in the oil palm-based cropping system is in food crops, and oil palm is planted between food crops. Under that system, people use local planting material (subspecies *dura*) rather than improved material (subspecies *tenera*). Farmer strategies with regard to oil palm are also affected by issues as soil fertility and the prevailing tenure rules.

Importantly, the oil palm-based cropping system at Adja plateau is divided into two steps. One stage is under palm (oil palm 'fallow'; *jachère à palmier à huile* – though technically not a fallow), a second stage consists of cropping fields (Fig. 1.1). On these fields (step 2), crops like cowpea, pigeonpea, groundnut and cassava are grown (Brouwers, 1993). Tenants can grow crops till oil palm reaches a height of 2 m, and through pruning they try to

postpone the moment when they have to end their cropping. In the stage afterwards, without crops, land owners keep the land fallow with dense oil palm (step 1). The length of that fallow is a response to the severe pruning practices. Both intensive pruning by tenants and long-duration fallowing by landowners are contested practices.

The climate on the Adja plateau is sub-equatorial with two dry seasons and two rainy seasons. The average yearly rainfall (69 years of observation) is about 1100mm. Rainfall is spatially and temporary highly variable.

Figure 1.1: The two phases of the oil palm-based cropping system
Left: Oil palm fallow, Right: Cropping field
Source: Field data

Soils are classified as Nitisols (FAO classification; *terre de barre*; sandy to sandy loam soils) and as *sols ferralitiques de dominance rouge* (in the French classification system). The fertility of the Nitisols of the Adja plateau strongly depends on organic matter content. Due to their texture (high amounts of sand) organic matter amounts are intrinsically low and hence these soils have low water retention capacity. An extensive pedological study of the region was undertaken by Azontonde (2000). His data also indicate that soils were poor in soil organic matter and were of low fertility status (Azontonde, 2000). In addition, on the Adja plateau, soil analysis from various fields under different land management techniques, showed nutrient flows from outfields to fields close to houses (Koudokpon *et al.*, 1994).

1.7 Objective

The present study's main objective is to explore and describe the political ecology of soil fertility in the oil palm-based cropping system. This has been reached by pursuing the following specific research objectives: (1) The socio-technical interfaces between various actors (landowners and tenants) in the OPBCS, (2) the institutional context above farm level

that affects cropping in the OPBCS and finally (3) the dynamic of soil fertility management changes as affected by the institutional context.

1.8 Research questions

My thesis addressed the following questions:

i. What are the constraints and opportunities for landowners and tenants with regard to soil fertility management practices in the OPBCS on Adja plateau? (chapter 2)

ii. How does land titling affect conflict (and conflict resolution) among landowners who claim the same plot? (chapter 3)

iii. How does land titling affect conflict (and conflict resolution) among landowners and tenants with regard to access to land for cropping purposes? The combination of both practices (chapter 3) led to the next research question:

iv. How does land titling and land access regulation affect soil fertility management practices by landowners and tenants? (chapters 3, 4 and 5)

1.9 Outline of the thesis

After this introductory first chapter, Chapter 2 presents farmers' perceptions of the socio-technical drivers for the low productivity of fields on the Adja plateau. The political context of soil fertility management on the Adja plateau is described as well. In Chapter 3, I used the advantage offered by a titling program in some villages on the Adja plateau to analyse the relations between land titling and soil fertility management in a quasi-experimental setup. In Chapter 4, I evaluate the competing claims between landowners and tenants on the same lands, the former competing for a long duration of oil palm fallow and the latter for the availability of sufficient fields for annual crops. In Chapter 5, I describe experiments in order to explore possibilities for improved soil fertility management, focusing on the role of organic amendments (household waste) in increasing agronomic use efficiency of fertiliser and in soil quality enhancement. The implications of my findings for the debate on sustainable agricultural intensification on the Adja plateau are discussed in Chapter 6, where I address the interplay of technical and social dimensions and discuss implications for policies to promote agricultural intensification.

Chapter 2

The political ecology of land management in the oil palm based cropping system on the Adja Plateau in Benin*

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Abstract

The Adja plateau (Benin) is densely populated by tenant and landowner farmers engaged in oil palm based cropping. Landowners use oil palm sap for production of *sodabi* (a local spirit), and an oil palm fallow (when no crops are grown beneath the palms) to restore soil fertility. Growing oil palm for palm oil is uncommon. Tenants access the land under specific contracts but are not allowed to plant trees. They grow food crops beneath the oil palm and extend the cropping period by severely pruning the trees because their right to crop is terminated when the trees become 2m high. The competing claims between landowners and tenants and between oil palm and annual food crops result in conflicts over practices that either degrade or restore soil fertility. Using a political ecology perspective, we examine how two overlapping institutions shape access to, and management of, land: the customary tenure system and the legal system introduced to regulate titling and contracting. These institutions have divergent implications for tenants and landowners, in terms of both social equity and land management practices. The implications of this institutional patchwork (bricolage) for joint learning to achieve sustainable agriculture are discussed.

Keywords: bricolage, customary land rights, institutions, oil palm fallow, political ecology, Benin.

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2.1 Introduction

Oil palm (*Elaeis guineensis*) is native to West Africa (Portères, 1962) but the world's largest production centres are now in Indonesia (36 % of global production) and Malaysia (47%) (Vissoh *et al.*, 2010). The crop has long had strategic importance in Benin. In 1856, King Ghezo of Dahomey (in the south of present-day Benin) initiated the palm oil trade and passed a law forbidding his subjects from cutting down oil palms. He allowed farmers to crop the land under the trees until the palms grew high enough to shade out the other crops. This permission resulted in farmers pruning the palm trees to slow their growth. When no crops are grown beneath the trees the land use is known as oil palm fallow (Kang *et al.*, 1991). Under conditions of land sufficiency and hence long fallow cycles the oil palm fallow is sustainable. Technically the Adja Plateau oil palm system is considered an agroforestry system constituted by complementary economic and ecological relationships between the crops and the palm trees. The decision by the Benin government in 1993 to make the oil palm sector a national priority and the subsequent revival of oil palm as a mono-crop has contributed to intensification of land conflicts (Fournier *et al.*, 2001), even in areas that are marginal for oil palm because of inadequate rainfall. Increased land scarcity and intensification of cropping in turn has resulted in more intensive oil palm pruning (and hence lower palm productivity), intensifying conflicts between landowners and tenants.

South Benin has the highest population growth rates in Benin and hosts 50 % of the country's population on only 7.7 % of the national territory (Mondjannagni, 1977). The high population pressure on the Adja plateau, where both the Adja and Fon ethnic groups live, implies that oil palm monocropping in commercial plantations would compete directly with food production. In fact, oil palm is not grown on the plateau primarily for its oil because the average annual rainfall (less than 1100 mm annually and highly variable, both spatially and temporally (Amoussou *et al.*, 2009)) is not conducive to high levels of oil production. The climate is sub-equatorial with bimodal rainfall. The soils are classified as nitisols (*terre de barre*; sandy to sandy-loam soils, according to the FAO soil classification) and as sols *ferralitiques de dominance rouge* (in the French classification system) (Koudokpon *et al.*, 1994). Such soils are intrinsically fertile (which explains in part the high population density on the plateau).

The oil palm based cropping system (OPBCS) combines oil palm grown by landowners for *sodabi* (a local commercial spirit) and food crops grown by tenants between the palm trees (Vissoh *et al.*, 2010). The landless tenants view any intrusion of commercial oil palm plantations into the OPBCS on the plateau as a threat to food production.

The intercropping practice traditionally consisted of a relatively long period during which the land was used for food crops, followed by a fallow period in which only the trees were grown in dense stands, typically lasting 15 years (Brouwers, 1993). Such extensive oil

palm fallow periods are known as *palmier jachère* (similar to the *jachère de manioc* described by Saidou (Saïdou *et al.*, 2009)). Technically the oil palm stage is not a fallow but a component of a contested cropping system. According to Brouwers (Brouwers, 1993), the OPBCS can be considered sequentially as two stages: an oil palm fallow stage and an intercropping stage with juvenile or more mature (but pruned) palm trees. Oil palm fallow restores soil fertility (Brouwers, 1993) and controls the aggressive cogon grass (*Imperata cylindrica*) (Vissoh, 2006, Vissoh *et al.*, 2010). At the end of the fallow period, the palm trees are cut down to extract the sap to make palm wine and spirits (Broek van den and Gbego, 1994); non-destructive tapping techniques are not commonly practised in this area. Thereafter, a new cycle can start based on the cultivation of food crops and palm seedlings on the same fields. The young palm trees of local provenance (cv *Dura*) are intercropped, with the permission of the landowner, with food crops such as cowpea (*Vigna unguiculata*), peanut (*Arachis hypogaea*), pigeonpea (*Cajanus cajan*), maize (*Zea mays*) and cassava (*Manihot esculenta*). The tenants try to prolong the period in which they are allowed to cultivate food crops by pruning the palm fronds. In contrast, in the oil palm belt of south-eastern Benin where higher rainfall allows intensive cultivation and encourages the use of improved oil palm cultivars (cv *Tenera*), food cropping underneath the palm trees typically is carried out for less than 5 years.

The high population density on the Adja plateau has implications for land access and tenure arrangements (Brouwers, 1993) which in turn have major implications for soil fertility management. Ownership of the land (and hence security of access) implies ownership of the oil palm trees planted on that land. The long-term social and technical sustainability of the OPBCS depends on the willingness of landowners to allow extended intercropping (and the consequent pruning practice) as long as the soil fertility, supposedly built up during the fallow period, is maintained. However, Brouwers' study did not show recovery of soil fertility due to fallowing, suggesting that the oil palm fallow may be more driven by landowners' concerns about maintaining their right of access to land rather than by agronomic considerations (Brouwers, 1993). Alternative tenurial arrangements do exist but appear to provide insufficient incentives to tenants to invest in soil fertility maintenance (Biaou, 1991). Land use practices have become politically charged and a cause of increasing tension between landowners and tenants. Soil fertility and land tenure issues are high on the development agenda on the Adja plateau. Technical advice about good practices is provided to landowners by the governmental extension service as well as by the research group of support to local initiatives for sustainable development, (*Groupe de Recherche et d'Appui aux Initiatives de Base pour un Développement Durable*-GRAIB). An American-led programme, the *Millennium Challenge Account* (MCA), has implemented a land titling project, from November 2007 to April 2011, that aimed to create a system of formal titling and registration (*plans fonciers ruraux*) throughout Benin (34 villages on the Adja plateau included). The

MCA attempted to demonstrate how to create effective and transparent governance of land, reduce the time and cost of obtaining a land title, and reduce the number of land disputes.

The present study examined from a political ecology perspective how the aforementioned pressures affect the social and agroecological dynamics of the OPBCS and identified options for soil fertility maintenance and land use under changing conditions. We document in this article the knowledge and practices of landowners and tenants and the ways in which their land management and tenure contracting practices are connected. Our analysis concludes that the conditions for sustainable development of the OPBCS depend on both technical and institutional conditions. We applied a political ecology framework (Blaikie, 1985, Benjaminsen *et al.*, 2010) in order to analyse the relationships between land and soil management practices and socio-institutional processes. Following presentation of our methodology the remainder of the article is structured in terms of performance constraints, soil fertility management practices and tenure arrangements, land tenure conflicts and state interventions.

2.2 Methodology

An overriding question guided this research: what are the constraints and opportunities to landowners' and tenants' farming practices in the oil palm based cropping system on the Adja plateau? Field research was conducted from March 2010 through March 2011. The term Adja plateau throughout this paper refers to the entire geographic area of the six administrative districts of Klouekanme, Toviklin, Lalo, Aplahoue, Dogbo and Djakotome (Fig. 2.1). The term *Adja farmer* refers to *ethnic Adja*. Similarly, the term Fon refers to ethnic Fon settled on the Adja plateau. The tenancy and ownership arrangements described are not specific to either ethnic group.

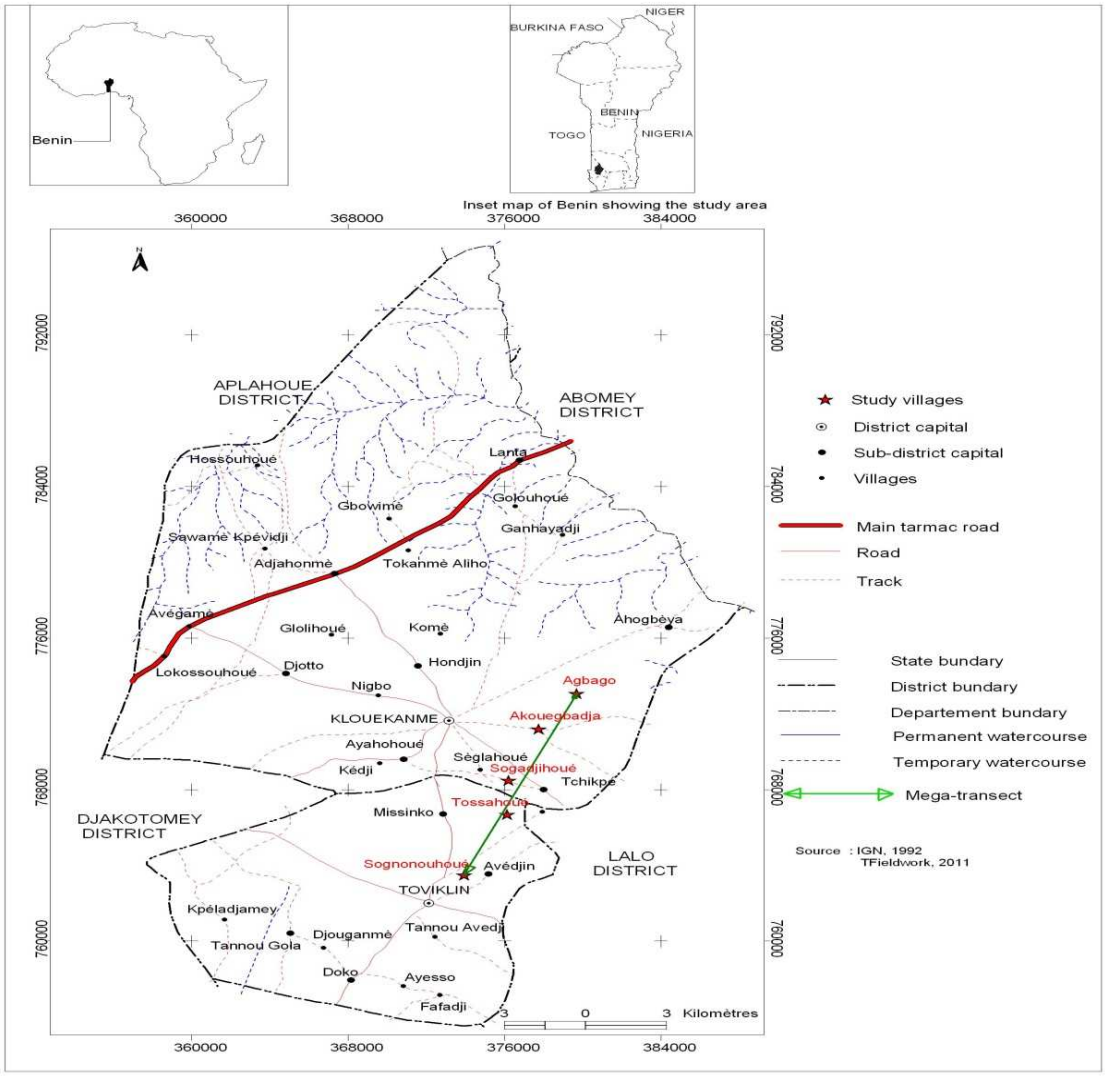

Figure 2.1: Map showing the study districts and the mega Transect

NOTE: There are 6 districts on Adja plateau. This study concerns 2 of them (Klouekanme and Toviklin). In total we investigated the situation in 3 villages and 2 hamlets attached to 2 villages. In this study, oil palm fallow has been found only on Nitisols. According to the FAO soil classification, the terre de barre or Nitisols are characteristic of plateaus, and are limited in organic carbon and potassium. However, Koudokpon has identified Acrisols on Adja plateau (not included in our study); the percentage of sand is, higher in these soils compared to nitisols

The study was conducted following a literature review and archival research. In collaboration with the extension service, GRAIB, MCA, and with reference to relevant literature about the Adja plateau (Kater, 1993, Houngbo *et al.*, 2008), two districts, Klouekanme and Toviklin, were chosen. The choice was based on the following criteria: OPBCS is the prevailing system of production (Kater, 1993, Houngbo *et al.*, 2008), local land

tenure arrangements that determine rights to grow and rights to harvest oil palm and food crops (Wartena, 2006), and recent interventions in land tenure arrangements.

A short preliminary visit allowed the first author to introduce himself to key persons and to explore the area's characteristics – such as farmers' participation in the titling programme, customary tenure, and ethnicity – through discussions with key informants (farmers, local leaders, market dealers, and extension staff). Subsequently, a transect line across the area was drawn at random on a map and a mega-transect of 20 km aligned northeast to southwest was conducted with the aid of a global positioning instrument. The five villages positioned along the transect were selected as research sites; two of these villages had participated in the MCA programme (Agbago and Sognonouhoue) and three had not (Akouegbadja, Sogadjihoue and Tossahoue).

The latter two villages turned out to be small and to share the same landscape; subsequently the farmers of both villages participated in joint focus group discussions [FGDs], and the findings were combined in the analysis. This allowed us to use the MCA programme as an experimental treatment so as to enable comparison.

Fifteen focus group discussions (Fern, 2001) were conducted, three in each of the selected villages, respectively composed on average of fifteen male landowners, fifteen male tenants and fifteen female tenants in order to provide detailed information on important local issues. The participants in each case were asked about cultivation under the oil palm trees and land tenure, conflicts, types of soils/land, criteria used to evaluate soil fertility, and innovations in soil and land management. The perceived constraints, their causes and opportunities were then ranked by the participants and options for techno-institutional solutions to alleviate the main constraints were jointly analysed.

Thereafter a survey with 90 random farming households using a semi-structured questionnaire was implemented. The random selection of respondents was based on a list of household heads that was constructed for each village, and triangulated with the chiefs and key informants in the villages. The randomly selected respondents represent a 20% sampling from the list of households heads. Each interview lasted for an hour approximately. Dependent household members might have different insights and options; hence we used information from the FGDs in addition. A joint workshop with farmers (3 village chiefs from Agbago, Akouegbadja and Sognonnouhoue, the president of oil palm producers' association of Klouekanme and 5 landowners and 5 tenants each per village of investigation) was held at the end of the field work to validate our findings.

The qualitative data from the key informants and FGDs were transcribed, from field diaries, flipcharts and tape recorder, into English and stored electronically; thereafter, related information served have been sorted and organized to generate the qualitative description. The quantitative data (relating to conflict resolution, nature of tenancy agreements, and number of

plots under various land tenure arrangements) from the survey were entered in EpiData (EpiData Association, Odense, Denmark; version 3.1) to calculate percentages of occurrence.

2.3 Results

2.3.1 The OPBCS performance constraints

The landowners and the male tenants mentioned poor soil fertility (Table 2.1) as the first ranked problem in all villages, except Sognonnouhoue where low rainfall was ranked first. Low rainfall was identified as the second most important problem. The female tenants ranked access to land as their first constraint, except in Sogadjihoue and Tossahoue where female face poor soil fertility as first constraint. The unavailability of mineral fertilisers often was ranked third by the landowners. In general, only tenants mentioned land tenure arrangements as a constraint. Poor soil fertility was attributed to several factors (Table 2.2). In Agbago and Akouegbadja, the burning of crop residues (which include pruned oil palm fronds) in itself was thought to reduce soil fertility over the long term. In the three other villages residue burning was not valued so negatively; in these villages oil palm fallow was ranked highly by landowners as a soil fertility management strategy (Table 2.3).

Table 2.1: Farmers' ranking of perceived factors shaping the OPBCS

Constraints	Agbago (N=55)			Akouegbadja (N=70)			Sogadjihoue & Tossahoue (N=30)			Sognonnouhoue (N=50)		
	Land-owners	Male Tenant	Female Tenant	Land-owners	Male Tenant	Female Tenant	Land-owners	Male Tenant	Female Tenant	Land-owner	Male Tenant	Female Tenant
Poor soil fertility	1	1	3	1	1	2	1	1	1	2	2	3
Poor rainfall	2	2	2	3	4	5	2	2	2	1	1	2
Unavailability of fertiliser	3	4	4	2	3	3	3	5	5	3	4	4
Lack of land & access to land	5	5	1	6	2	1	7	3	3	6	5	1
Weed damage	4	7	5	7	7	8	6	3	3	4	7	5
Pest damage	6	6	6	8	8	9	4	6	6	5	6	6
Lack of credit	7	3	7	9	9	4	5	7	7	7	3	7
Field flooded	-	-	-	5	6	7	-	-	-	-	-	-
Lack of market to sell food crop	-	-	-	4	5	6	-	-	-	-	-	-

Source: FGDs: male landowners, male and female tenants, April to October 2010

Table 2.2: Farmers' ranking of perceived causes of soil fertility degradation

Possible causes	Agbago (N=55)			Akouegbadja (N=70)			Sognonnouhoue (N=50)			Sogadjihoue & Tossahoue (N=30)		
	Land-owner	Male Tenant	Female Tenant	Land-owner	Male Tenant	Female Tenant	Land-owner	Male Tenant	Female Tenant	Land-owner	Male Tenant	Female Tenant
Demographic pressure on limited lands	2	2	2	2	2	2	1	1	1	1	1	1
Lack of rotation	3	3	3	3	3	3	2	2	3	2	2	2
Ploughing	4	4	4	4	4	4						
Lack of crop residues to cover soil with	5	5	5	5	5	5	3	4	2	4	4	4
Burning of pruned oil palm fronds	1	1	1	1	1	1	4	3	4	3	3	3

Source: Male landowners' and male and female tenants' focus group discussions, April to October 2010

3.1.1 Soil fertility management practices

The respondents listed numerous practices (Table 2.3) for maintaining soil fertility. Mineral fertiliser is used and ranked first as the main strategy for maintaining crop yields by both landowners and tenants in Agbago and Akouegbadja while those in Sognonnouhoue and Tossahoue ranked this strategy second in importance, behind application of household waste (a mixture of compound wastes from many sources).

Table 2.3: Farmers' ranking of strategies to cope with low yields and poor soil fertility

Land management practices	Agbago (N=55)			Akouegbadja (N=70)			Sognonouhoue (N=50)			Sogadjihoue & Tossahoue (N=30)		
	Land-owner	Male Tenant	Female Tenant	Land-owners	Male Tenant	Female Tenant	Land-owner	Male Tenant	Female Tenant	Land-owner	Male Tenant	Female Tenant
Household wastes	2	-	2	2	-	2	1	1	1	1	1	1
Synthetic fertiliser	1	1	1	1	1	1	2	2	2	2	2	2
Oil palm fallow	10	-	-	10	-	-	3	-	-	3	-	-
Rotation cowpea/maize	3	2	5	3	2	5	4	3	3	4	3	3
Rotation peanut/maize	3ex	6	6	3ex	6	6	4ex	3ex	3ex	4ex	3ex	3ex
Residue burning	-	-	-	-	-	-	6	5	5	6	5	5
Non-burning of on-field biomass	11	-	7	11	-	7	9	-	-	9	-	-
Pigeon pea	7	-	-	7	-	-	7	-	-	7	-	-
Cassava fallow	5	5	3	5	5	3	8	-	-	8	-	-
Mucuna	-	-	-	-	-	-	10	-	-	10	-	-
Acacia spp fallow	-	-	-	-	-	-	11	-	-	11	-	-
Sweet potatoes	-	4	-	-	4	-	-	-	-	-	-	-
Natural fallow	8	-	-	8	-	-	12	-	-	12	-	-
Tomato	6	3	4	6	3	4	-	-	6	-	-	6
Plough/ridges	9	7	-	9	7	-	-	-	-	-	-	-

The cultivation of tomato (and, by male tenants only, possibly also sweet potato), which are always fertilised, was mentioned frequently as a response to poor yields of other crops, mainly in Agbago and Akouegbadja, suggesting that the fertiliser used on this market crop was regarded as beneficial for subsequent crops. In Agbago and Akouegbadja, the male tenants interviewed said they did not bring household wastes to the rented fields unless they had security that the wastes would benefit their crops in the subsequent cropping seasons. It has been observed by the extension agents that when tenants apply wastes to the rented fields, certain landowners claim back the fields in order to benefit from their improvement by the waste application. Oil palm fallow was ranked third by landowners in these latter two villages. Other forms of fallow that were mentioned by these landowners were *Mucuna* fallow and *Acacia auriculiformis* fallow. Cassava fallow was mentioned especially in Agbago and Akouegbadja and was ranked as important by landowners and tenants, both male and female. Natural fallow was always ranked very low by landowners. Rotations between maize and legumes (cowpea, peanut) were ranked relatively high by landowners and tenants in all villages.

The landowners in Agbago, subsequent to the confidence they gained through land registration that resulted from the MCA's intervention, mentioned their willingness to let tenants access and crop their land following an oil palm fallow. The landowners in both Agbago and Akouegbadja did not burn biomass on their oil palm fields (claiming that this practice was detrimental to soil fertility; Table 2.2, Table 2.4) while this practice was still followed in the other villages, where it was considered to contribute to soil fertility. Some landowners, and in some villages also female tenants, referred to the importance of using the mulching palm fronds as mulch; male tenants did not rank this practice.

Female tenants in all the investigated villages reported growing a cowpea variety (*egbamonlou* in the Adja language) that is perceived by both male and female tenants to have a negative effect on soil fertility but that fetches the highest market price of all cowpea cultivars. In the discussions many farmers mentioned (Table 2.4) their willingness to experiment with varieties of cowpea cultivars, including the testing of *egbamonlou*. Landowners, preferring to combine household waste application with the addition of a small amount of mineral fertiliser, also expressed interest in experimenting with soil fertility management options; however, their favoured practice, being partly a function of the nature/quality of the organic matter, demands a long term experimental design. In addition, landowners and tenants wish to evaluate the practice of ridging in relation to soil fertility management, since there is a clear difference in practice between *Adja* and *Fon* farmers.

Table 2.4: Options jointly identified for technical and institutional innovation (N= 70)

Farmers	Technical options	Institutional options
Landowners	A learning platform The use of household waste The use of mineral fertiliser Effect of oil palm fallow on subsequent crops	Written contracts (to avoid tenants' establishing claims to the land). Reduction of duration of rental agreement, to 3-4 years Land registration
Male and female tenants	Stop burning pruned fronds on -field The rotation of legumes and cereals Use of cow dung / household refuse Burying crop residues in the soil Use of mineral fertiliser	Written contract (to prevent landowners chasing them off the land. Associate the chief of village to any transaction. Written contract to clarify the custom of 'land gifts' so that children can inherit securely

Source: Akouegbadja village group discussions (N=70), April to October 2010

3.1.2 Land tenure regimes at village level

Access to land for farming is unequal. Land can be accessed under a number of arrangements, resting on permanent or non-permanent rights (Table 2.5). Two main types of permanent landholding were identified, family lands and individual lands (either by patrilineal and matrilineal inheritance or by purchase, *doukohwoue*). There were no chiefs' holdings or government lands in the investigated villages. Adja women have no land inheritance rights and have to rely for access on one or other of the non-permanent arrangements described in the next section. The *doudeasso* tenure arrangement (Table 2.5) was found only in Sogadjihoue, Sognonnouhoue and Tossahoue. The farmers in Agbago and Akouegbadja knew about this system of tenure, but have abandoned it.

3.1.3 Land tenure conflicts at village level

The ambiguity and non-respect of tenure arrangements (Table 2.5) are often sources of conflict over land. Conflicts occur between tenants and landowners in the case of *doudeasso* when tenants are reluctant to quit the land. In order to keep the land for a longer time than was implied by the agreement, tenants severely prune the palms to prevent them from reaching the critical height of 2 m. Landowners, realizing that intensive pruning can substantially prolong the time that tenants can remain on the land, have decided that tenants have to give up the tenancy and leave the land after 25 years. One tenant in a village where doudeasso is still practised shared his case:

"*I got this land via doudeasso in1986; I have been cropping since then by severely pruning the oil palm trees which never grow over 1 m. Now I am almost at the end of the rental*

period. In previous times, the planting of oil palm trees was included in doudeasso arrangement and, if lucky, one could plant oil palm on the rented land before conflict arose, ,and one's rights were saved. If not, the risks of losing the land before the end of the 25 years were not negligible. Nowadays, the right to plant oil palm trees has been removed from doudeasso and the renter has only the right to grow food crops" (A tenant named after Tohou, Sognonouhoue, 26/04/2010)

In the case of *deman* (sharecropping), the risk of conflict arises when the tenant tries to take all the profit from the harvest without sharing the profit with the landowner. As soon as a landowner is aware of this happening, he forces the tenant off the land even if the term of the contract has not expired. *Ahaya*, renting, is also a source of conflict. Land is rented out usually for a period up to 5 years. After one year the landowner might rent out the same land to other tenants, who then tend then to fight over their cultivation rights and acts of vandalism occur. Often, the conflict ends in negotiation with the landowner; typically the resolution means that the 'surviving' tenant must pay two to three times the fee originally agreed. Another practice is that, if the landowner is in need of cash, he sends one of his relatives to argue that the tenant is using of family land, and threatening to claim it back; in this case, too, the tenant is forced to pay extra to retain access to the land and the right to cultivate.

Table 2.5: Land tenure arrangements for access to land and oil palm trees

Tenure arrangements	Type of land, crops	Tenure rights	Other terms & conditions
doudeasso,pledge or mortgage	Food crop land, oil palm land	All cultivation rights, including oil palm trees. The land is to be returned after the trees reaches the height of 2 m. Not used in Klouekanme anymore. Nowadays, it is fixed at 20 or 25 years by landowners.	In the past, the critical height was not well-defined; landowners do not use a tool to measure height. The practical guideline was that it is reached when the tenant or landowner is not able anymore to touch the first palm frond or nuts while standing under the tree. This marks the end of the contractual arrangement for tenants. When the tenant is taller than the landowner, the critical height does not have the same meaning for them both and this has caused many conflicts in the past. The 2 m rule has been institutionalized and marks the end of the contract; it has evolved from a tenants' right to plant oil palm trees as well as food crops, and become restricted to only food crops.
Deman (2/3),& deman (1/2), sharecropping	Food crops land, oil palm land, palm oil trees	40-50 years' ago, a cultivation right that included oil palm trees. The palm nuts were shared between the tenant and the landowner. Nowadays, it covers only the crop harvest. There is no right to tap palm wine, nor sell trees or collect nuts. The tenant is not allowed to transfer the right of cultivation to a third party.	In 1945-1950, the rate of 2/3 of the yield went to the tenant and 1/3 to landowner. Nowadays, because of shortage of land, landowners claim half of the yield and agree to purchase the synthetic fertiliser. Obligations are shared when shift in deman nature occurs.
Ahaya, rental	Farm land with severely pruned oil palm trees	Cultivation right against a yearly payment. Cultivation right can be transferred to a third party. Food crop can be cultivated but there is no right to plants oil palm tree on the land. The land must be returned at the end of the contract (typically, 3 to 5 years).	The crops are managed by the renter only. The fee is paid annually; the level depends on the land fertility. 5000 FCFA/bowive per year for fertile lands, 2000 FCFA/bowive/year for less fertile.
Dekanhlouehloue,oil palm contract	Oil palm fallow (*dekan*), oil palm trees	The purchase of young palm trees gives a right to harvest the trees and the tapped wine. The land beneath the trees might be farmed by the landowner.	The purchase is often made by an alcohol distiller in need of a secured supply of sap.
Aikougbanwhihoue, Borrowing	Farm land	All cultivation rights, not including trees. No delegation to a third party.	

Source: Male landowners' and male and female tenants' focus group discussions, April to October

When conflicts do arise, 66 % of respondents (landowners and tenants) stated that they resorted to the political administration to resolve the case (Table 2.6); only 6.6 % said that they try to make a friendly settlement. 7.7 % go to the law court, a few had tried a resolution through the police office; somewhat more (18.6 %) said that they tried to find a resolution by discussion between the families involved. The disputes are the harder to resolve because most contracts (93 %) are oral and only 7 % of contracts in our sample were written. Of the six written contracts, only one had been witnessed by the legally-designated authority. The oral contracts were more often witnessed than not; however, on this score we found that there were some minor differences between the villages

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Table 2.6: Conflict resolution, by institution regulating resolution (N=90)

Participation in land titling programmes		Number of resolved conflicts, by the institutions regulating the resolution				
	Study villages	Between family members	Political administration	Police office	Law court	Through friends
MCA	Agbago	4	24	-	-	-
-	Akouegbadja	3	17	-	5	1
-	Sogadjihoue	-	5	-	-	2
-	Tossahoue	-	8	-	-	3
MCA	Sognonnouhoue	9	6	1	2	-
	Total no. (% of total)	16(18.6)	60(66)	1(1.1)	7(7.7)	6 (6.6)

Source: Heads of Households survey (N=90), April, October 2010

Note: Agbago, Akouegbadja and Sogadjihoue in Klouekanme had been influenced by *PGTRN* land titling intervention in the past. The numbers represent cases of conflict, which had recourse to the specific institution noted. Empty cells mean no information.

3.1.4 State intervention related to land tenure on the Adja plateau

State intervention in land tenure started in the early colonial era and the colonial land tenure laws remained effective after Benin achieved independence in 1960. Articles 711, 712, and 716 of the French civil code, and the 1935 decree (dated November 15th, 1935, on landholding rules and regulations in the French West African colonies) are the main legal provisions applicable to the identification and management of property, and they fall under the administration of the state and local authorities. The decree of May 2nd, 1906, in its first, second and third articles, which set up a system for recording written agreements between indigenous parties, is another example of colonial legislation that persisted into the independence era.

In addition, in 1931, the government of Dahomey signed a circular (Circular N^{o} 128AP of March 19th) on customary tenure which until recently has served as reference. In 2007 a new law (law 03 of October 16th) and a decree (law 618 of October 22nd 2008) have

been approved and signed. The law of 2007 is the latest to govern land tenure in Benin. However, several of its articles do not take into account the actual conditions that have been revealed in our study of landowners and tenants. Article 73, for example, does not recognize a fallow period longer than 5 years and as a consequence oil palm fallow (dekan) is omitted entirely. Article 68 does not recognize farmlands less than 2 hectares, excluding almost all of the Adja plateau's smallholders. Article 43 refers to the creation of multi-level structures (on which the MCA has based its land tenure measures) and article 47 forbids contracts that are not written and not witnessed, thereby effectively making illegal the kind of personal oral agreements revealed in our study.

In 1995 a government programme was initiated for the management of territories and natural resources (*Programme de Gestion des Terroirs et Resources Naturelles*-PGTRN) that began to issue and register land titles, beginning in six villages in Klouekanme. In 2006 the MCA's land titling and registration programme, in collaboration with the Benin government, was initiated in association with GRAIB, which became the local executor of the land titling programme. GRAIB is connected to various multi-level state services such as the village level land management service (*section villageois de gestion foncière* -SVGF), the sub-district level land management committee (*sous-commission de gestion foncière d'arrondissement* -SCGFA) and the district level land management committee (*comité de gestion foncière* -CoGeF).

Table 1.6 describes the impact of the titling programmes. The data suggest that only in Agbago, Akouegbadja and Sogadjihoue, where both land titling programmes were undertaken, written contracts have begun to be used. It is interesting to note that these three villages also record the most frequent resort to the political administration for conflict resolution. Tossahoue, which did not benefit from either of the titling programmes, records the largest number of cases of contracts based on oral agreement without witnesses. However, in a nearby village, Sogadjihoue, which has been influenced by the PGTRN titling programme, the number of oral contracts without witnesses has substantially reduced and oral contracts are witnessed in mass. This study recorded one case of a written contract, witnessed by the authorities, in Agbago, a village whose practices have been influenced by both titling programmes.

Currently, subsequent to the titling and registration programmes, tenants in Agbago and Sognonnouhoue (where the MCA land titling programme took place) find themselves excluded from access to land and cultivation rights. Tenants, who have been excluded from the titling and registration effort, reported that they were chased off the land they were cultivating when land registration became imminent: they are not the landowner and their cropping rights were not taken into account when no witness could attest to their tenurial contract. This negative consequence of land titling underlies tenants' perceptions of the

interventions that might benefit them (Table 2.4) by securing their access to land and cultivation rights in the OPBCS.

3.2 Discussion

This study has analysed a situation in which landowners use a long fallow for various purposes: soil fertility regeneration, weed suppression and to back up their claims to the land. Tenants have access to the land to crop on the basis of short-term tenure but try to prolong the tenure period through the (sometimes severe) pruning of oil palm to prevent the trees growing to a height of 2 m. However, the OPBCS at present is not a win-win situation; rather, it can be described as an arena in which competing claims on cropping practices and land ownership are linked with beliefs about soil fertility decline and restoration.

Brouwers described the fallow period as primarily a soil fertility management strategy in an integrated agroforestry system (Brouwers, 1993). Our analysis points instead toward an explanation based primarily by land-owners' interests in long-term control over land. The differences between owners' and renters' perspectives and practices regarding land access issues highlight the ways that the oil palm fallow emerges from tensions among divergent actors rather than by design as an integrated agroforestry practice. Changes in agronomic practices, production constraints and local land tenure regimes are closely intertwined with the socio-political dynamic between land-owners and land-renters. Complex interactions between customary and formal legal land titling and tenure further complicate the dynamic.

This study has analysed the actors' rankings of constraints (Tables 2.1 and 2.2) and thereby revealed discrepancies between the five villages. We speculate that differing perceptions of the importance of (declining) rainfall, might not indicate differences in weather patterns between the villages so much as differences in the ability of the soil to retain water i.e. in water-holding capacity, that are related to different levels of soil organic matter. In Agbago and Akouegbadja, the practice of slashing and burning the oil palm fronds is linked by the farmers to the claim that the soil is becoming impoverished. This claim suggests that the idea that continuous pruning is in itself bad for the soil is a common belief, which they then rationalise by linking the soil fertility to the practice of burning rather than pruning. Landowners and tenants both perceive that household waste (an important source of organic matter) is generally ineffective for the first subsequent crop and effective in boosting yields only in the second and third year. Their perception of a delayed effect partly explains the fact that tenants, (contracting cultivation rights under only three years' tenure) do not apply household waste. This response has been found also among tenants in Ghana (Adjei-Nsiah *et al.*, 2004, Oladele *et al.*, 2011) where migrants with insecure rights do not invest in long-term soil fertility management.

Two important institutions shape access to and management of land on the Adja plateau: customary tenure and formal, legal land rights and contracts. These two categories

elsewhere have been opposed respectively as informal versus formal, traditional versus modern, or socially embedded versus bureaucratic constructs (Cleaver, 2002). Each set of terms has its own connotations concerning the desirable pathways for institutional evolution. (North, 2005) has defined institutions as the rules of the game that remove uncertainty in human interaction, a definition that emphasises reduced uncertainty and lower ambiguity. However, West African tenure systems seem to be characterised by ambiguity. (Adjei-Nsiah *et al.*, 2008) for instance has shown that ambiguity is integral to the tenure system around Wenchi, Ghana. The ambiguity of the current situation on the plateau – with both customary tenure and the more recent efforts to put in place a formal, legal tenure system –has the potential to increase competing claims on the Adja plateau, as has occurred elsewhere under comparable circumstances (Adjei-Nsiah *et al.*, 2008). Formal legal land titling and contracts are seen to disadvantage tenant farmers because the formal contracts increase the power of those who are already in stronger positions (i.e. the landowners). Cleaver introduced the concept of institutional *bricolage* (patchwork) to recognise the coexistence of institutions, that are likely to co-evolve in indeterminable ways, rather than to evolve in predictable linear fashion whereby one institution is replaced by another, more modern one (Cleaver, 2002). A consequence of bricolage is that the institutions governing tenure do not reduce or remove uncertainty and to some extent maintain it. Institutional innovation through formal titling programmes runs the risk of increasing tenants' insecurity because the power to manoeuvre in such ambiguous situations is not equally divided among landowners and tenants. The landowners effectively use the patchwork of institutions as political tools.

Currently the two tenure systems exist uncomfortably together. The *doudeasso* land arrangement, found only in Sognonnouhoue, has been abandoned by land-owners in Agbago and Akouegbadja because they considered that it reduced their power and gave too many land rights to the tenants, who thus could keep cropping and pruning at their own convenience. The *ahaya* and the *deman* are currently the dominant land tenure arrangements in our study area and both are of short duration. Tenants typically have limited rights on these lands and are sometimes chased off the land in which they have invested to improve soil fertility. Similar cases have been reported from Ghana and central Benin (Adjei-Nsiah *et al.*, 2004, Saïdou *et al.*, 2004). These instances continue to occur, despite the fact that tenants and landowners may live in the same village or sometimes even in the same household. These tenants, short of land, do not have enough security under these tenure arrangements to invest in long-term soil fertility management and because it is evident that the landowners will take the profit from the improved soil fertility (especially if the perceived delayed effect of household waste proves to be true).

Although the land titling and registration effort seeks to reduce uncertainty, the social equity of its effects may be questioned. At present the patchwork of access rules and cultivation rights in the oil palm agroforestry system permit tenants to access land and grow

food crops but the cost is paid both in terms of soil fertility and in tenants' security. Our data suggest that these tensions could be relaxed by clearer agreements between both parties based on a clarification of rights and non-authorized practices, and formalization of the rights enshrined in the customary land tenure arrangements between owners and tenants.

This study made use of a natural experiment in the form of the MCA's formal land titling programme, which contributed to the exclusion of tenants operating under customary arrangements for access to land and the right to cultivate food crops The changes in land tenure is shown in our study to undermine the long-term oil palm fallow land use system, echoing findings from other political ecology research (Zimmerer, 1990, Steinberg, 1998). State intervention by means of formal land titling and registration has allowed landowners to use their land as collateral for credit. However, the intervention also opens up the possibility that others will lose land through default and by the sale of land to people outside the farming community. A common consequence of such a dynamic is that it can be expected to concentrate land ownership and disenfranchise smallholders and renters. The local politic around claims to titles to land in practice privilege landowners and undermine the flexibility of the local land tenure system. Male and female tenants are the losers. Further, registration penalizes the holders of secondary land rights – especially women and herders; these rights are not recorded in the register and are more easily dismissed in disputed claims (Toulmin, 2008). The social dynamic in this case closely echo those described by Schroeder in the Gambia, where male landholders effectively took control over land through practices promoted by a development project that did not pay attention to the female gardeners' rights (Schroeder, 1993).

The government of Benin has added to the pressures created by the changes in land tenure and titling by launching a national oil palm plantation policy designed to increase oil production. However, this policy has overlooked the fact that the Adja plateau is not suitable for large-scale plantations aiming to produce palm oil. It does not take into account the aspirations of landowners and tenants in the OPBCS and thereby in effect it has created another potential source of competing claims, as has occurred elsewhere under comparable circumstances (Carney, 1993). Under the conditions described in this article, actions to regulate the tension between landowners and tenants by means of consultation and negotiation that involves also the local authorities (Delville *et al.*, 2002), could be encouraged. Such consultation and negotiation have proven to be successful elsewhere in Benin (Saïdou *et al.*, 2009).

Written contracts between landowners and tenants are beginning to be used though still somewhat sparingly and the resort of both parties to witnesses and administrative authorities (Table 2.6) is increasing. The written contracts in existence during our investigation relate to (i) the *doudeasso* a pledging, agreement; (ii) the *dekanhlouehloue*, relating to palm tree contracts; and (iii), land purchases. However, written contracts that

express the rules of customary land tenure are never a perfect solution because of the rigidity they bring to local land transactions. Written contracts also must be registered with and enforced by legal authorities, implying additional costs in the form of fees, and observance of the letter of laws such as the land tenure law of 2007. Moreover, it is not clear exactly what kind of endorsement written contracts dealing with customary arrangements might necessitate because (at present) they do not resemble a formal legal document (Delville, 2002). There are so many omissions and unwritten conditions in the certificates drawn up by farmers that the exact nature of the rights they confer is unclear. Similarly, the legal inconsistencies in Benin's land tenure law of 2007 raise questions about its applicability and functioning.

3.3 Conclusion

This study has demonstrated how the technical and institutional dimensions of the OPBCS are intertwined, with negative consequences for tenant security and soil fertility.

The challenge of sustaining or improving the OPBCS on the Adja plateau requires further research in several fields. The nature of the biophysical and social dynamic of soil fertility in the oil palm fallow remains an unsolved contextual question. For example, the mechanisms by which soil fertility is affected by use of fertiliser and organic amendments, the choice of crops and cultivars tenure arrangements, and the power balance between landlords and tenants, are not yet known. An ethnography soil fertility management practices, including analysis of the actors' knowledge about soil fertility and the social organization and performance of those practices, would help to provide an answer (Richards, 1993, Jansen and Vellema, 2011). The various land management practices offer the possibility of creating a research design for identifying and measuring the mechanisms of soil degradation and/or maintenance (Nuijten, 2011). Participatory soil fertility experiments could be conducted with landowners and tenants in the villages of Akouegbadja and Agbago to study oil palm fallow in relation to the various ways of using household waste in order to co-produce effective technologies that are biophysically effective and socially acceptable within the given institutional context.

Tenants and landowners recognize that land tenure, state intervention and the law to an important extent determine their capacity to produce oil palm products. It is argued in this article that the challenge is not only to develop soil fertility management strategies for higher yield but also to bring about institutional transformations within which such strategies would become rational for tenants and landowners. The current patchwork of socially embedded customary land tenure arrangements and bureaucratic formal titling programmes would need to be blended, to create a hybrid system, if the negative effects of replacing informal by formal tenure systems are to be avoided. While studies suggest that promoting tenure security is the efficient way to promote investment in land management (Beekman and Bulte, 2012),

such institutional changes might transform the OPBCS from a zero-sum agroforestry system based on competing claims into a win-win situation.

Chapter 3

Revisiting land reform: land rights, access and soil fertility management on the Adja Plateau in Benin*

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Abstract

In the oil palm-based cropping system on the Adja Plateau land titling plays an important role. Landowners argue that the oil palm fallow (*dekan*) restores soil fertility, but in the long-term such a tree fallow is also an instrument in the struggle for control over land. A land-titling programme in the study area allowed an analysis of the relationships between titling and soil fertility management that showed two different institutional effects with socio-technical consequences. *Titling* increased land security for landowners. While this increased owner security initially reduced access to land for tenants, a subsequent introduction of *witnessed paper-based contracts* enhanced tenants' access to land and improved their security of tenure. Improved titling and more secure tenure reduced conflicts over land and opened possibilities for agricultural intensification. This change was associated with a shift from long-term oil palm fallow to shorter-term land management practices. In these shorter-term arrangements tenants and landowners increasingly invested in land through rotations between maize and cowpea (rather than maize mono-cropping) and the use of mineral fertilisers. The new arrangements did not result in an increased use of household waste. The paper suggests that sustainable agricultural intensification requires institutional changes in both, land ownership and rental agreements to access land, that are based on a mixture of customary and formal rules.

Keywords: land titling; tenure security; soil fertility, political ecology, legal pluralism

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4.1 Introduction

In Africa, land tenure reform is key to increased production (Obeng-Odoom, 2012), soil fertility restoration (Beekman and Bulte, 2012) and conflict management (Lind and Sturman, 2002). Much of the debate revolves around two distinct ways for approaching such institutional change. Some authors argue that land policies should be rooted in African customary land tenure systems (Platteau, 2000, Benjaminsen *et al.*, 2008, Sjaastad and Cousins, 2008, Toulmin, 2008, Knight, 2010, Yami *et al.*, 2011, Obeng-Odoom, 2012); while others propose that neo-liberal individualist tenurial systems are more effective and desirable (Soto De, 2000b, Saint-Macary *et al.*, 2010). Regardless of their differences, both camps argue that the reduction in uncertainty brought about by institutionalised land tenure reform would reduce conflict over land and stimulate sustainable agricultural intensification.

In an effort to improve land tenure and reduce rural poverty, Benin has in selected areas embarked on a *Millennium Challenge Account* (MCA) land titling programme from 2007 to 2011. The programme's objectives were to reduce the time and cost of obtaining a land title, facilitate secure land transactions, and reduce the number of land disputes through the creation of an effective and transparent land and property governance process. The rationale for these objectives was the claim that the inconsistencies between customary rules and state land law, and the oral character of the land transactions and land access did not result in equitable land access and tenure security, thereby intensifying tenure conflicts (MCA-Benin, 2009). The claim that the legal pluralism (Griffiths, 1986, Benda-Beckmann von, 2002) created by the co-existence of customary and formal land property and access rules is responsible for conflicts does not go uncontested (Platteau, 1996). It has been observed that the patchwork resulting from such legal pluralism can help reduce conflicts about access to land as actors creatively engage both state and customary institutions, what Cleaver (2002) calls *bricolage*.

On the Adja plateau in Benin, conflicts about land arise from two major sources. The first is contestation of land ownership. According to a report by MCA-Benin (2009), more than one thousand conflicts are brought to the regional courts annually, constituting over 90% of the total caseload. The second source is access to land, due to informal and unstable rental agreements. Tenants claim to have little or no motivation to restore or improve soil fertility because they expect their landlords to chase them off when they see improvements in land productivity. Meanwhile, landowners claim that tenants actually contribute to soil fertility degradation.

These contradictory claims are especially important in the oil palm-based cropping system (Brouwers, 1993), which comprises a phase with food crops interspersed with juvenile oil palms, alternated by a phase with only mature trees and no food crops, known as oil palm fallow (*jachère de palmier* in French or *dekan* in Adja). Characterised as an agro-forestry

system with beneficial economic and ecological interactions between the palm trees and food crops (Brouwers, 1993), the system has also been shown to be an arena in which landowners and tenants struggle about control over land. The system is therefore best studied by using a political ecology lens (Yemadje *et al.*, 2012). Our earlier study showed that landless tenants experienced reduced access to land as an outcome of the MCA land-titling programme (Yemadje *et al.*, 2012). The implementation, in a number of villages in our study area, of this MCA programme, in support of Benin government's policies offered an opportunity to study land titling in action and gain insights that might be relevant for the theoretical debate about land reform in Africa.

The current paper examines how implementation of formal land titling affected (a) the number of conflicts around land ownership, and (b) land access rules; and (c) how these changes affected investment in soil fertility management by both landowners and tenants. In particular, we look at investment in mineral fertilisers and organic amendments, at the willingness to intercrop legumes with cereals, and at the use of the oil palm fallow. During analysis, conflict reduction and improvement of tenure security are regarded as intermediary outcomes of land titling, and changes in soil fertility management practices as final outcomes. Knight (2010: 19) defined tenure security as the "reasonable guarantee of land rights, supported by the certainty that one's rights will be recognized by others and, when challenged, protected by legal and social remedies". The effects of land titling on soil fertility management are analysed using a political ecology lens, which provides a framework for analysing relationships between institutional and technical agro-ecological practices (Andersson *et al.*, 2011) particularly in terms of conflicts, power, and equity in access to and control over natural resources (Jarosz, 2012).

4.2 Socio-technical background to land contracts

The institutional practices that currently constitute land ownership and land use rights on the Adja plateau are dynamic and diverse, ranging from customary (or neo-customary, as some customary practices were in fact imposed by the colonial powers) oral agreements, to informal paper contracts '*petits papiers*' (Edja, 2001, Delville, 2002), to formal paper contracts and finally to registered (and legally protected) paper titles. Both the colonial power (France) and the independent government of Benin have shaped the institutions that regulate ownership and access. In the 1950s, the colonial government initiated measures for the management of local oil palm plantations that aimed to increase tenure security for economically vulnerable farmers.

After independence on August 1 in 1960, access to most land continued to be decided on an individual, household or family level, with a clear increase in sharecropping arrangements (Brouwers, 1993). Farming by women became increasingly important since the 1970s and 1980s (Brouwers, 1993) and this process continues till the present day. In the

1990s, women had access to around 24% of the land, and, while they can purchase land for commercial cropping, this does not happen very often frequently (Biaou, 1991).

Immediately after Independence in 1961, the Government of *Mathieu Kerekou* initiated an agrarian reform (law 61-26 of 10 August 1961), which established cooperatives for managing oil palm plantations on land, which was expropriated with limited compensation for the original land owners (Le Meur, 1995). This led to large-scale land withdrawal from landowners in southern Benin, exacerbated unhappiness about the earlier colonial measures and armed revolts and emigration of unhappy landowners (Edja, 2001). Today these cooperatives have become more or less dysfunctional with continued litigation, ineffective management and low productivity. Similar problems with litigation by former landowners plague commercial oil palm plantations established in Ghana on land under customary ownership.

In 1993, the government of Benin (with support from the World Bank) initiated a pilot project for natural resource management (*Programme de Gestion des Ressources Naturelles* – PGRN). This was followed in 1999 by the Programme of Land and Natural Resource Management (*Programme de Gestion des Terroirs et des Ressources Naturelles* - PGTRN) of which a large section was devoted to the development of experimental land tenure plans (*Plan Foncier Rural* – PFR) in a representative sample of 41 municipalities.

This set of experiments had two primary objectives: (1) to ensure greater tenure security to facilitate agricultural investment and land viability; (2) to collect information on the socio-institutional conditions for adapting rural land legislation. The wording of the first objective indicates that, on a theoretical level, the government and its agencies assumed that increased and formal (rather than customary) tenure would result in agricultural investments based on using land as collateral for credit. The land tenure document issued after this experiment gave rise to Law 2007-03 of 16 October 2007, which established a rural land tenure framework in Benin, the basis for the final MCA land intervention in the country. The *PFR* is a gradual governmental policy while the MCA is an implementation body of the *PFR* on Adja plateau. The MCA emphasized on the implementation of the policy, and the change in land rental agreement was undertaken at a later stage by the MCA and not by the original *PFR*.

This is the context within which the MCA-Benin land-titling programme began in 2006. Its objective was stated as follows: “to ensure fair access to land, guarantee security of investment in land, and efficient management of tenure conflicts, so as to contribute to poverty reduction, to the consolidation of social peace and harmony, and to the realisation of integrated sustainable development” (MCA-Benin, 2010). The MCA programme was funded by the Millennium Challenge Corporation under an agreement with the government of Benin and in support of its land tenure policy. The objectives of the MCA suggest that it follows an individualistic, neo-liberal conception of land property right in that it intends to systematically

record and formalise rights through state institutions, with the objective of ensuring the security of ownership and encouraging agricultural investment.

MCA was implemented in 9 districts and established PFRs in 300 communities, with village-based land management platform (*Section Villageoise de Gestion Foncière* – SVGF) to which important legal powers are legally conferred. On the Adja plateau, the MCA land titling programme was implemented in 34 villages, 10 of which are in the Klouekanme District. When a diagnostic study (Yemadje *et al.*, 2012) showed that the process of establishing ownership actually reduced access to land for tenants, a second phase was initiated, which focused on formalising access agreements.

The contract between landowners and tenants, whether formal, informal, customary or 'modern' is formalised in terms of the size of the land rented, the duration of the agreement and rights to crop. Such contracts often have been a source of tension. In the Klouekanme district, land was most often allocated to close relatives (family members, including wives) in short-term agreements. This pattern of allocation was largely driven by the landowners' fear that they would lose their land to dishonest tenants. Before the intervention by MCA, the customary contracts between landlords and tenants were reinforced by regular symbolic gifts and material assistance provided by tenants to landlords.

Maintaining a relationship of social reciprocity is customarily an important condition for tenants to maintain their access to land. For example, under the customary loan (*Ahaya*) type of agreement, the landlord and tenant are often close relatives. Family relationship implies that the tenant runs little risk of being evicted, as long as he/she meets the standards set by the landowner. In the borrowing type of agreement (*Aikougbanwhihoue*), landowners rent their land to selected tenants who are considered to be of good character. Here too, landlords and tenants treat each other as part of one family. The selection of tenants is often based on confidence, estimation of skills and membership of the in-law family. Tenants help landlords when it comes to burials or other family issues. In other cases, landlords compel tenants during the morning to work on the owners' fields, the afternoons being available for work on the contracted land. Landowners put up land for a sharecropping type of agreement (*Deman*) when they are too busy with off-farm activities or because they have large tracts of land to work themselves. Under this type of agreement, the tenant has to give one-third of the harvest to the landlord, or half of the harvest when the landlord provides mineral fertilisers and seeds. Also in this case, landowners demand a lot from tenants in terms of morality and responsibility. Again, both parties consider and treat the other as part of one family, which implies obligation to assist each other in difficult periods of life. In some cases, when the tenant is the landowner's wife, both man and woman work in the field together. Such arrangements illustrate that customary agreements about access to land are embedded in social relations, which hamper the evolution of purely individualistic tenure arrangements.

4.3 Research area, data collection and analysis

4.3.1 Research area

Field research was conducted in Klouekanme district on the Adja Plateau, (Fig.3.1), which is of mixed Fon and Adja ethnicities (Wartena, 2006). The climate on the plateau is sub-equatorial with bimodal annual rainfall with an average of less than 1100 mm with high spatial and temporal variability (Amoussou *et al.*, 2009). These conditions are not conducive to high levels of palm oil production and for that reason most trees are used for producing palm wine or spirits. Oil palm is a major element of the tenure system (Edja, 2001).

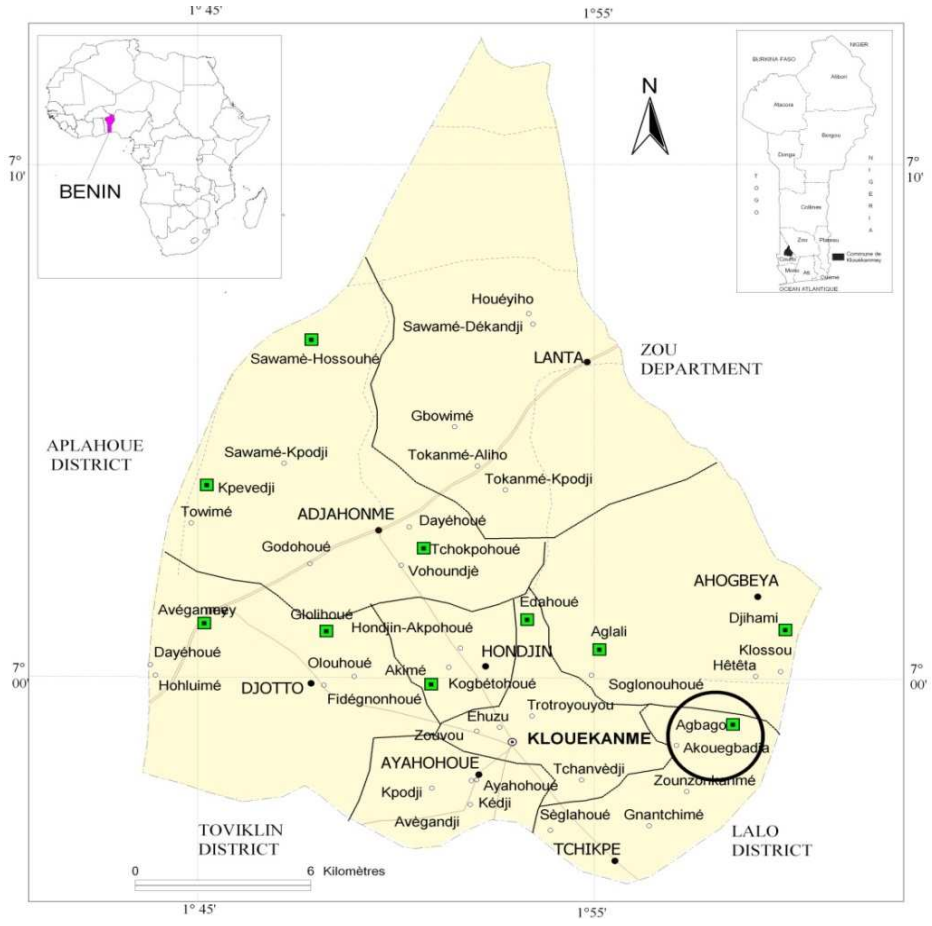

Figure 3.1: Map of Klouekanme showing villages where the MCA programme was implemented (green squares) and the two villages (experimental and control) that were taken for detailed study

4.3.2 MCA programme implementation

The research reported in this paper was not conducted in conjunction with the MCA programme, but instead uses the MCA land-titling programme as opportune natural experiment (Galiani and Schargrodsky, 2010), wherein the implementation of land titling in some villages acts as the 'treatment' and its absence in other villages as the 'control'. Our research was conducted in two stages (Table 3.1): a) at the large scale, 10 MCA villages were compared with 120 non-MCA villages with respect to conflicts over ownership; and b) at the local scale, Agbago (an MCA village) and Akouegbadja (a non-MCA village) were compared with respect to practices related to land access and use. Both Agbago and Akouegbadja are in the same sub-district (*Tchikpe*) and have similar geographies. At the larger (district) scale, we compared MCA and non-MCA villages before and after the intervention. At the local scale we compared the MCA and the non-MCA village only after the intervention. We recognize that this with-and-without-treatment research design is not quite as strong as a before-and-after-treatment design, but we are confident that it allows insights into the effects reported at both scales, which are at least partially consequent upon, and likely to be attributable to the MCA intervention.

Table 4.1: Methods of data collection, level of investigation and nature of data collected for each research question

Nature of data collected	District level of investigation (130 villages)		Village level of investigation (Agbago and Akouegbadja)	
	Qualitative	Quantitative	Qualitative	Quantitative
Research question 2: How does land titling affect conflict between landowners?		Archive files from the conciliation law court of Klouekanme from 2002 to 2012 to compare 10 MCA villages with 120 non-MCA villages	1. Seven cases of land conflicts analysed in Agbago. 2. Informal discussions with village chief and aged landowners.	Survey in an MCA (Agabgo) and a non-MCA village (Akouegbadja).
Research question 3: How does land titling affect land access rules? **Research question 4**: How do land titling and land access rules affect soil fertility management practices?	1. Informal discussion with: the "*Responsible Communal de Promotion Agricole*", the CoGEF members, and GRAIB (an NGO). 2. Review of literature for socio-technical background (*diagnostic foncier d'Agbago*)		1. Participant observation of 10 landowners and 10 tenants from 2010 to 2012. 2. Informal discussion with: landowners and tenants. 3. Review of literature for socio-technical background (*diagnostic foncier d'Agbago*)	Survey in an MCA (Agabgo) and a non-MCA village (Akouegbadja).

Note: Research question 1 is dealt with in Chapter two

4.3.3 Data collection and analysis

Three research questions guided this study: (1) How does land titling affect conflict (and conflict resolution) among landowners who claim the same plot? (2) How does land titling affect social relations between (the legally recognised) landowners and tenants? (3) How does land titling affect land management practices by landowners and tenants?

At district level, data were collected from 2002 to 2012 from the archives of the law court of conciliation of Klouekanme, where land ownership disputes are resolved. (Conflicts about rental agreements usually do not reach this court). At the village level, we targeted 462 fields plots randomly selected in Agbago (235 plots) and Akouegbadja (227 plots). Participation in the MCA is treated as the independent variable and the social dynamics of land access and soil fertility management as dependent variables. Survey data were analysed using chi-square analysis with Fisher's exact test at $P < 0.05$.

4.4 Results

4.4.1 Land ownership and conflict reduction

Table 3.2 compares the ex-ante and ex-post situations for both the MCA and non-MCA villages. It shows that before the intervention in the MCA villages significantly more land conflicts occurred than in the non-MCA villages (chi-square = 67.4; $P < 0.001$). The same difference is obtained after the intervention (chi-square 11.4; $P < 0.001$). However, comparing the ex-ante and ex-post situations brings to light a significant decline in the number of conflicts in the MCA villages (chi-square = 9.4; $P < 0.01$), while the non-MCA villages do not show a significant decline ($P > 0.05$). This outcome suggests that the titling programme reduced the number of conflicting claims on ownership. Interestingly, even after the MCA intervention, the number of ownership conflicts after supposed land transactions did not diminish, suggesting that implementation of the titling programme was not entirely conclusive.

Further analysis of Table 3.2 suggests that apart from claims on ownership, other sources of land conflict were more widespread in the non-MCA villages, and that they persisted in them, whereas they disappeared in the MCA villages. However, this number is low and does not lend itself to separate statistical analysis. Conflict about cropping rights by tenants appear to be insignificant. However, it is likely that such conflicts are not brought to the (formal) law court of conciliation at Klouekanme, but submitted (and sometimes resolved) at lower (customary) courts.

Table 3.2 Land tenure conflicts based on archival records before and during the titling programme in non-MCA and (future) MCA villages

	Before MCA implementation (year 2002-2006)		During MCA implementation (year 2007-2011)	
Sources of conflict: Claims on ownership or usufruct based on:	Non-MCA villages (N= 120 villages)	(Future) MCA villages (N=10 villages)	Non-MCA villages (N= 120 villages)	MCA villages (N=10 villages)
Purchase of land	214	58	207	33
Common inheritance	20	5	0	0
Unclear field boundaries	5	0	4	0
Single inheritance	7	0	1	0
Sold oil palm fallow land (*Dekan*)	1	0	1	0
Tenancy rights to crop	4	0	0	0
Total	251	63	213	33
Conflict / village	2.1	6.3	1.8	3.3

4.4.2 Landownership, land access, and tenure security

We now turn to the results of the in-depth analysis of the two villages. Tables 3.3 and 3.4 show the number and nature of conflicts in respectively Agbago (MCA village) and Akouegbadja (non-MCA village). Table 3.3 provides some indication that more conflicts occurred in Akouegbadja (N=16; 8% of the total conflict cases) than in Agbago (N=7; 3% of the total conflict cases), but due to the relatively small numbers (for most plots no conflicts were recorded), the difference was not (quite) significant (Fischer's exact test; $P = 0.054$).

Table 3.3: Occurrence of conflicts between landowners and tenants about access land in the non- MCA and MCA village (by individual plots)

	Non-MCA village (Akouegbadja)	MCA village (Agbago)	Total
No conflict occurring	219	220	439
Unclear land boundary	4	2	6
Claim on common heritage	4	1	5
Conflict due to the oral character of arrangement	4	1	5
Conflict due to the ambiguous character of the arrangement	3	1	4
Conflict due to non-respect of terms of the arrangement	1	2	3
Total	235	227	462

Source : Field Data

During MCA implementation, programme managers encountered informal paper contracts ('*petits papiers*' also called '*reçu d'achat'*) regarding land ownership. The signing of such transaction papers was witnessed by the children of the seller, often in front of the village chief (who did not sign the papers himself). Because of the multiplicity of forms of

petits papiers and their ambiguity, it was evident that the choice of witnesses was very important. Legitimacy or credibility of witnesses affects the status of the contract. The ambiguous status of *petits papiers* also resulted in unwillingness to engage in contracts with outsiders, and most land transactions were in fact intra-familial. Because of their ambiguity, MCA sought to replace *petits papiers* with formal contracts. However, their proposal for a formal template was not accepted because the municipality of Klouekanme had designed its own template for transactions. Currently, the latter template is in use. Contracts based on it are signed by both the village chief and the mayor in front of the SVGF platform members. While this template suggests a strong tendency to legalise land transactions, we observed that the status of the signing witnesses (village chief and mayor) is different in that the signature of the mayor is considered the more important one. The introduction of these contracts by the Municipality of Klouekanme and the MCA appears to have resulted in an increase in the use of *petits papiers* also in non-MCA villages, where land property rights were not yet formally registered.

Table 3.4 lists the kind of agreements about land access in both villages. The relative number of paper-based contracts (*petits papiers*) was significantly higher in Agbago (Fisher's exact test; $P = 0.017$), indicating an increased interest in some form of formalisation of agreements about access to land after the titling program. Also significantly more plots were rented out to tenants in Agbago than in Akouegbadja (Fisher's exact test; $P < 0.001$). This difference reflects landowners' increased confidence that tenure contracts will be adhered to, which translates into a greater willingness to rent out land. However, the data also show that many plots in both villages are used by their owners without proof of title (Table 3.4). Somewhat contrary to Table 3.2 (where analysis is done at communal scale), differences between the two villages for plots owned with or without title were not significant ($P = 0.09$), although the proportion of plots under paper-based title (ownership and use rights) was somewhat higher in the MCA village Agbago than in Akouegbadja (42.3% versus 31.1% in bold).

Table 3.4: Agricultural use of fields and rental agreements

	Non-MCA village N=235	**MCA village N=227**
	%	%
Used by owner, without title	47.6	30.9
Used by owner, with title	**21.3**	**16.3**
Used by tenants of which	31.1	52.9
-Paper-based, non-witnessed	**9.8**	**26.0**
-Not paper-based, non-witnessed	21.3	26.9
Total	100	100

Note: Agreements for land used by tenants in the non-MCA and MCA village in 2012 after land titling (in number of plots)

The introduction of formal land contracts also affected the nature of agreements about land access. While initially almost all rental contracts were unsigned and un-witnessed, the intervention of the MCA changed the nature of such agreements. MCA has proposed templates for contracts, not yet in uses, which give more recognition of tenants' rights. In all, four kinds of documents have been prepared for future use. The arrangements covered by the new documents are: (i) *contrat de bail pour la plantation d'arbres* (a long-term rental contract to regulate the right to plant trees in commercial plantations); (ii) *contrat d'amodiation de parcelle* (a sharecropping arrangement); (iii) *contrat de location de parcelle* (a short-term rental agreement to grow food crops without the right to plant trees); (iv) *contrat de prêt de parcelle à titre gratuit* (a short-term agreement where no monetary transaction is involved, often used in cases of land transactions within families or among people with moral obligations as in families). All contracts are issued on behalf of the Municipality of Klouekanme. They are to be signed by both parties, four witnesses (two for each party involved) and the village chief, but not by (or behalf of) the mayor of Klouekanme, indicating that such contracts are even more in the customary realm. All contracts have six sections: (1) identification of the parties concerned; (2) the purpose of the contract and identification of the plot; (3) the specific conditions of the agreement; (4) the obligations of both parties; (5) the conditions under which the contract can be annulled; (6) a ruling about the management of complaints, which indicates the importance of reconciliation and social peace rather than formal justice. This last section makes clear that conflict resolution should first be attempted through local mediation, by a person chosen by both parties. This section also firmly places such contracts in the customary, rather than in the formal-legal realm. This choice is understandable, considering the lack of capacity of the formal legal system to deal with complaints. From the Table 3.3, between three percent (MCA village) and seven percent (non-MCA village) of the plots still are sources of conflict. When scaled up to all the plots in the village, and all the villages in the district, it is clear that conflict resolution cannot be the responsibility of only the formal legal realm. These new contracts were not yet operational in 2012, but observations in the villages clearly show that people already act as though this new system of regulating access to land has been implemented.

4.4.3 New contracts, tenure security and agricultural investment

The changes in tenure security as a consequence of the titling and the subsequent new (proposed) forms of rental contracts created a new environment in which landowners and tenants allowed new decisions regarding investment in agriculture and soil fertility. Such investments should be seen in a context in which pressure on land is increasing the need for more permanent forms of cropping, without extended fallows.

Table 3.5 documents such changes for plots, used by either field owners or by tenants, in respectively Agbago and Akouegbadja. Landowners and tenants in Agbago both used more

mineral fertiliser than in Akouegbadja (Fisher's exact test $P < 0.001$ and $0.01 < P < 0.05$ respectively). Neither group of land users showed increased use of household waste after the titling programme ($P > 0.05$ in both cases). Interestingly in Agbago, landowners but not tenants more often intercropped cowpea with maize than in Akouegbadja ($P < 0.002$ and $P > 0.05$ for landowners and tenants). The use of oil palm in agricultural fields decreased more in Agbago than in Akouegbadja ($P < 0.02$).

Two lines of evidence suggest that MCA land titling and subsequent introduction of new rental agreements are contributing to the demise of the oil palm-based cropping system. First, on the Adja plateau, oil palm (and other trees) indicated field boundaries and oil palm fallow was often used as proof of land ownership. The oil palm fallow evolved not only to restore soil fertility but also as a land security strategy for landowners in situations where land use would otherwise be contested by other landowners or tenants. That use has become less relevant. Second, there is an increased willingness among landowners and tenants to invest in soil fertility (increased use of legumes as a crop in rotation; increased use of mineral fertiliser), which implies less reliance on oil palm fallow for soil fertility management.

Table 3.5: Soil fertility management practices by landowners and tenants in Akouegbadja (non-MCA village) and Agbago (MCA-village)

	Non-MCA village (Akouegbadja)		**MCA village (Agbagbo)**	
	Landowners (%) N=163	**Tenants (%) N=72**	**Landowners (%) N=107**	**Tenants (%) N=120**
Cowpea rotation	66.87	75	84.11	84.16
No cowpea rotation	33.12	25	15.88	15.83
Use of mineral fertiliser	77.30	83.33	92.52	93.33
Non- use of mineral fertiliser	22.69	16.66	7.47	6.66
Use of household waste	51.53	69.44	58.87	64.16
Non-use of household waste	48.46	30.55	41.12	35.83
Intercropping with oil palm	31.28	22.22	7.47	9.16
No intercropping with oil palm	68.71	77.77	92.52	90.83

Source: Field Data

Among the four kinds of contracts whose implementation has been planned, there is an entirely new one that allows tenants to plant trees. This would include the planting of hybrid oil palms, in accordance with the priorities for the oil palm sector defined by the Government of Benin. Such contracts would have a duration of 20 to 25 years, making them very different from the short-term contracts typical for food crops. It remains to be seen to what extent this new possibility would allow a revival of the old oil palm-based cropping system; or whether it would lead to commercial plantations, in which case the new option would increase the competition with land for food production. Such contracts might also

enable a new type of absentee elite tenant who invests in plantations to establish use rights on land.

4.5 Discussion

This study has documented changes in land ownership and rental agreements due to the introduction of land titling and new forms of paper contracts by MCA, and related these changes to debates on tenure and access to land. Often the debate has been framed in dichotomous terms between two systems of tenure, with an assumption of a linear evolution from customary to formal (and from communal to individualistic) rules (Platteau, 1996). However, such models take too simplistic a view and give insufficient attention to institutional pluralism and the ambiguity that could result from multiple institutions (Chauveau *et al.*, 2006, Adjei-Nsiah *et al.*, 2008, Lund and Boone, 2013)

On the Adja plateau, we see three different types of changes in contracts dealing with access to land: (1) from oral to written contracts, probably inevitable in societies that become increasingly literate; (2) from un-witnessed to witnessed contracts, where the capacity to mobilise witnesses that have sufficient credibility and legitimacy is important; (3) from contracts backed up by local chiefs under customary rules to contracts backed up by the state in a legal system. With regard to the last change, we observed an interesting difference between contracts related to property (signed by the village chief and the mayor of Klouekanme) and those related to secondary access rights (signed only by the village chief). At first sight this difference suggests that property relations have become more formalised especially since landowners seem to consider the signature of the mayor more valuable than that of the village chief. This observation suggests that property contracts relate to competing institutions and thereby contribute to debates about the nature of the authority that has the legitimacy to settle conflicts about property (Lund and Boone, 2013).

We observed another example of legal hybridisation that is closer to the customary end of the spectrum, in the form of the rules that relate to rental agreements, including agreements under which the use of the land is given for free. These are formal contracts backed up by customary institutions, i.e. not the '*petits papiers*' that existed before. Still, these new types of contracts provide little certainty for the landless tenants. However, the fact that they are on official paper (of the Klouekanme Municipality, though not signed by its mayor), contain the signature of the village chief, and those of two witnesses from each party involved, suggests that the contract is also backed to some extent by local government and indirectly the state. Two developments are likely to be responsible for this hybrid nature of new contracts. First, under the legal system, the state does not have the capacity to regulate conflicts related to rental agreements. The number of cases to be dealt with (around 5% of all plots) would be beyond the capacity of the state to resolve (Edja, 2001). Such hybrid contracts reflect what Lund and Boone (2013) call the politics of jurisdiction: a competition for

authority, in which ability within the customary domain effectively to deal with issues helps define, reproduce and maintain customary authority. This competition could possibly reproduce itself rather than lead to institutional closure (Lund and Boone, 2013). According to Obeng-Odoom (2012), however, individualist systems inevitably drive out communal systems. If, in plural systems, institutional competition maintains ambiguity, one cannot claim, as do the more structuralist definitions of institutions (North, 2005), that institutions reduce 'uncertainty in human interaction' (Adjei-Nsiah *et al.*, 2008).

These three changes in the nature of agreements are happening concurrently, albeit at different rates and without fixed endpoints. Coexistence of customary and formal land access rules is therefore likely to be inevitable. Moreover, it is also an outcome desired by many of the parties involved. Further evidence is provided by the fact that many plots of land continue to be owned without title. Apparently, the link between titling and landownership can be indirect, i.e. when titling changes the perception of tenure security even if the process of formal and legal titling has not been completed (Obeng-Odoom, 2012).

As noted above, the new forms for rental agreements have not yet come into general use. However, many people know that they will soon be implemented and already effectively act upon them, as shown by the differences between Agbago and Akouegbadja. For that reason, we suggest that they simultaneously reflect and further cause institutional change. It will be especially important to further study contracts that allow tenants to plant trees, as these would support long-term agreements that would disconnect the right to plant trees from ownership of the land. With such contracts, commercial plantations of (high-yielding hybrid tenera) oil palms could become increasingly important in Adja (even though the area is not agro-ecologically suited to palm oil production, as noted earlier). Such commercial undertakings could initiate a process of increased competition over land between tenants with short-term contracts for annual crops and new entrepreneurs with long-term contracts for tree crops. If these new entrepreneurs are able to better leverage the hybrid institutional system, or move it more towards a more formal and individualistic system, new struggles over land could arise, potentially threatening the intensification of food cropping on the densely populated Adja Plateau.

This study shows that once ownership issues were clarified, landowners were more willing to enter into more formalised rental contracts. Taken together, increased willingness by landowners to engage in rental contracts and increased trust between landowners and tenants enhance options for agricultural intensification. Under that scenario, the use of long-term oil palm fallow appears to have become less necessary, neither for reasons of recovering soil fertility, nor as a strategy to keep tenants from over-pruning palm trees as a means to extend their use of the agricultural land. Under agricultural intensification, soil fertility could be maintained through increased use of fertilisers and possibly of organic waste by both

landowners and tenants. However, we were unable to demonstrate that an increased number of farmers apply organic waste.

This study contributes to the debate on formal and informal tenurial laws and rules in sustainable agriculture in Africa. It is situated between the two theories of pathways for institutional change: towards customary institutions (Platteau, 2000, Pritchard, 2013) and towards state institutions (Soto De, 2000b). Our empirical analysis of land tenure practices contributes to a better understanding of the role of law in society, law and human agency, and the strategic uses of law in specific situations of competition or conflict. The implication of our research is that land access rules do not evolve in a linear fashion and that application of blueprints is not necessarily the best option for institutional change. The use of linear blueprints and their foundation in state institutions, or 'institutional mono-cropping' (Evans, 2004) generates systems that have little variety or flexibility in their rules that would allow them to be effective in highly diverse ecologies (Ostrom and Basurto, 2011). Our study shows that the state institutions regulating land access can evolve in ways that simultaneously complement and compete with customary land institutions, leading actors in the system of legal pluralism to creatively engage in institutional *bricolage,* drawing on both formal and customary institutions.

Paper-based registration for temporary rental arrangements was not the original objective of the MCA. That element was developed after the program became aware that land titling led to reduced opportunities for tenants to access land for farming. The new opportunities provided by paper contracts for tenants to access land on the Adja plateau trigger the issue of recognition of customary rules by formal land law. According to (Knight, 2010), a land law that seeks to recognize customary land rights must allow space for custom to freely evolve so that it can continue to address the changing land-related needs of community members, and yet include protection against those customary practices that perpetuate discrimination and inequity.

The institutional reconfiguration brought by the MCA intervention appears to contribute to the demise of the oil palm-based cropping system and allows further agricultural intensification. Investment in soil fertility through increased use of mineral fertilisers was noted subsequent to the MCA intervention. These investments by tenants are a consequence of the enhanced trust and higher security provided after the legalisation of formal land ownership.

We agree with (Peters, 2009) on the urgency of re-launching the debate on the form and content of public land tenure interventions. Many rules are unwritten and many written laws are not followed as rules (Ostrom and Basurto, 2011). The new use of paper contracts for formalising land access arrangements seems to succeed in giving more status to local municipalities as institutions capable of resolving local conflicts without having to resort to using the legal institutions of the state. In such contracts, maintenance of local peace seems

more important than seeking justice under the law. Hence, both local municipalities and the state in a hybrid performance each play their own roles in regulating ownership and subsequent secondary rights to land (Shipton and Goheen, 1992). Such hybrid institutions could become key to economic development.

4.6 Conclusion

This study revealed mechanisms of institutional change, which lead to technical changes in agricultural practices and subsequently to changes in soil fertility management. In response to the MCA land titling and rental contract intervention, landowners' soil fertility management, embedded in changing land tenure institutions, is shifting from long-term cycles of oil palm fallows and cropping, to short-term strategies for land rental and fertiliser use. Institutional changes were implemented in the form of paper-based (but not necessary legal) contracts. These new contracts combine formal land titling with customary tenure arrangements, maintaining legal pluralism in the laws regulating land use on the Adja Plateau. The study therefore confirms the need to take into account existing practices when institutional reconfiguration is attempted. Land management practices need to be understood and the plurality of land access rules need to be accepted before land registration and titling is attempted. Such interventions should avoid the use of legal blueprints.

Many successes have emerged despite policy rather than because of it (Pretty *et al.*, 2011). The evidence from research in sub-Saharan Africa shows that many of the benefits assumed to stem from land titling are not automatic, and, in some circumstances, titling may have the opposite impacts from those expected (Toulmin, 2008). The policy insights arising from our research suggest that international development projects and donor agencies should strengthen customary arrangements for increased tenure security, which, in combination with increased trust, can become a vehicle for sustainable agricultural intensification. We, therefore, suggest a flexible model of institutional and technical change that captures the complexity of the land access rules in West Africa. Consultation with landowners and tenants through multi-level innovation platforms potentially leads to win-win solutions that avoid the risks of blind application of legalistic blueprints (Hounkonnou *et al.*, 2012). Finally, in the interest of complementing our present quantitative research approach, we recommend further analysis of land tenure change through ethnographic research on actors' practices and strategies of institutional *bricolage* within the oil palm-based cropping system.

Chapter 4

The role of fallow length in soil fertility restoration in the oil palm-based cropping system on Adja plateau, Benin

Abstract

The oil palm-based cropping system is a perennial intercropping system that dominates on the Adja plateau, Benin. A long-term cropping period (food crops, mixed with palms less than 2 m high) is alternated by a long-term (10-30 years) oil palm fallow. The duration of the fallow is contested: landowners claim that long-term fallows are essential for soil fertility recovery, whereas tenants suggest that the long-duration is rather an indication of the wish of landowners to control access to land. An early study did not demonstrate enhanced soil fertility recovery after long-term fallowing, suggesting that the practice needs to be understood from a political ecology perspective. The aim of our study was also to contribute to resolving the competing claims between landowners for oil palm fallow and tenants for cropping fields. We compared fallows of different duration (10, 15 and 20 years) with cropping fields and tested whether soil quality (biological, chemical and physical soil quality) improved due to fallowing and fallow duration. Our findings indicate that biological (activity of earthworms and arbuscular mycorrhizal fungi) and chemical soil fertility (organic matter contents, amounts of nitrogen and phosphorus, plant performance) were not higher in fallows that in cropping fields and did not increase with fallow length. Physical soil fertility (bulk density, a proxy for workability of the soil) increased after fallowing and was highest in the oldest fallows. The implications of these findings for the debate on sustainable agricultural intensification on Adja plateau are discussed.

Keywords: agroforestry; arbuscular mycorrhiza; earthworm; political ecology; sustainable farming

5.1 Introduction

Long fallow cycles, through which nutrients and organic matter regenerate (Nye and Greenland, 1960) and pests, weeds and pathogens are suppressed (De Rouw, 1995), have been used in shifting cultivation in West Africa (Koutika *et al.*, 2005). Increasing demographic pressure has reduced availability of fertile land, resulting in shortening of fallow duration. In response to this change, planted trees fallows, with an emphasis on nitrogen-fixing legumes, have been suggested to improve soil fertility, allowing a shortening of the fallow period (Sanchez *et al.*, 1997). Several authors have demonstrated the usefulness of tree fallows on the restoration of chemical soil quality (Manlay *et al.*, 2002), biological soil quality (Kandji *et al.*, 2001, Hauser *et al.*, 2012) and physical soil quality (Lal, 1996). Relevant properties of the trees include the ability to fix atmospheric nitrogen and the amount of nitrogen fixed, decomposability of leaf litter and its resultant effects to soil life, and properties of the root system that could impact on soil porosity and bulk density (Schroth *et al.*, 1996).

However, the issue of optimum fallow duration, in relation to demand for agricultural fields, has not often been addressed explicitly. (Mertz, 2002) reviewed some 300 publications on the relation between fallow length and crop yield and noted that only a very small number of them was potentially useful for addressing that relation. It was also noted that a negative effect of shortening fallow duration was often assumed, starting with the qualitative model of (Guillemin, 1956) but also in mathematical models of shifting cultivation (Dvorak, 1992, Gilruth *et al.*, 1995). Mertz (2002) also made clear that fallow duration cannot only be understood in terms of soil fertility and soil management, but needs to be seen in a wider socio-economic and socio-cultural context.

On the Adja plateau, south-western Benin, a specific kind of intercropping system occurs, known as the oil palm-based cropping system (Brouwers, 1993). The system is characterised by long-term growth of food crops, interspersed with oil palms (*dekanvi*: young oil palm trees less than two m high, due to severe pruning, mixed up with food crops; step 2 in Fig. 1.1), alternated with long-duration fallows (*dekan*: oil palm fallow - in Adja language step 1 in Fig. 1.1). Because of the ecological and economic relations (the food crops stage is used by tenants, the fallow stage by landowners) between the oil palm tree and the annual food crops, the system has been described as an agroforestry system. The oil palm is of the traditional *dura* type, not of the improved *tenera* type, and hence unsuitable for palm oil production. The climate on the Adja plateau is also not conducive to palm oil production, as rainfall amounts are too low. The oil palms in the fallow stage are used to make *sodabi*, a local alcoholic beverage. The system had earlier been described as a sustainable system for maintaining soil fertility (Brouwers, 1993, Vissoh *et al.*, 2010). The oil palm-based cropping system became prominent in the 1960s after regression of the traditional bush fallows on the entire Adja plateau (Brouwers, 1993). Landowners consider a duration of 15 years fallowing as optimal for soil fertility regeneration. However, their wish for long-duration fallows

conflicts with the strategies of tenants who prefer land for food crops (Koudokpon *et al.*, 1994, Wartena, 2006, Vissoh *et al.*, 2010). Increasing agricultural intensification and commercialisation of agriculture on the plateau has the potential to increase the conflict. The system has for that reason also been described as a political arena for competing claims on land by landowners and tenants (Yemadje *et al.*, 2012). Interestingly, the claim of soil restoration through the oil palm-based cropping system has not been confirmed in studies. (Koudokpon *et al.*, 1994) were unable to demonstrate improved chemical soil quality after fallowing. Because palm fronds are continuously removed from fields for other purposes, such as thatching, nutrient export from the system without replenishment would make a role in improving chemical soil quality unlikely. However, Koudokpon suggested, without showing data, that fallowing did improve physical soil quality, as fallowing would increase organic matter inputs which would result in higher amounts of soil organic matter and higher soil biological activity, both of which would contribute to improved soil structure. Another study also suggested that restoration of biological soil quality might play a role in explaining beneficial effects of long-duration fallows (Duponnois *et al.*, 2001). A study in Ivory Coast established changes in soil quality after establishment of *Chromolaena odorata* in fallows in humid savannahs (Tondoh *et al.*, 2013), while another study did not report significant changes under short-term fallows in Senegal (Masse *et al.*, 2004). The large quantity of biomass with high amounts of nutrients by *C. odorata* is likely the main factor improving soil quality (Tondoh *et al.*, 2013)

The mechanisms of soil fertility improvement (if any) by the oil palm fallow remain elusive and call for investigating the effects of fallowing and fallow duration on biological, chemical and physical soil quality. Among the biota that occur under oil palm fallow, we focused on arbuscular mycorrhizal fungi and on earthworms. Arbuscular mycorrhizal fungi are abundant and ubiquitous in almost all ecosystems and form mutualistic associations with over 80% of vascular plants (Smith and Read, 1997). Next to their role in improving plant nutrition through the enhanced uptake of immobile elements such as phosphorus (Cardoso and Kuyper, 2006, Carvalho de *et al.*, 2010), they also contribute to soil structure (formation of aggregates; (Jeffries *et al.*, 2003)). Oil palm is dependent on and responsive to arbuscular mycorrhiza (Phosri *et al.*, 2010). Earthworms improve soil structure and their casts are enriched with organic carbon and mineral nutrients (Saïdou *et al*., 2008).

This research wants to contribute to the debate about the importance of fallowing and fallow duration in the oil palm-based cropping system for soil fertility regeneration. It should thereby also make a contribution to the *contested access debate (*Yemadje *et al.*, 2012*)*. We used the analytical methods of science to test the competing claims by landowners and tenants. We used a biophysical perspective to refer in general terms to the political forces and the ramifications of the contested access (Ribot, 1998). The paper echoes on the issue of *access to resources* in the framework of political ecology: whether the oil palm fallow

improves or not soil quality is decisive in understanding its political role as an instrument for owners to retain control over land as well as controlling tenants' access to it.

5.2 Material and Methods

5.2.1 Study site

The study was conducted on the Adja plateau, located in the oil palm belt in south-western Benin at 230 km from Cotonou. Experiments were set up in the district of Klouekanme at two different locations on the Adja plateau. The oil palm fallow and cropping fields at Akouegbadja village are located between 6°56' 09" and 6°59'56" N and 2°53'21" and 1°55'20" E, and those in Sognonnouhoue village, located between 6°24'49" and 6°55'16" N and 1°50'49" and 1°54'43" E. Fallows and cropping fields were not more than 5 km from each other.

The average annual rainfall on the plateau is less than 1100 mm. Rainfall is highly variable, both spatially and temporally (Amoussou *et al.*, 2009). The climate is sub-equatorial with bimodal rainfall. The soils are *sols ferralitiques de dominance rouge* classified as nitisols (*terre de barre*; sandy to sandy-loam soils, according to the FAO soil classification) and as Eustrustox (USDA soil taxonomy (Azontonde, 2000)).

In collaboration with the extension service on the Adja plateau, and after consultation of literature on the area, two municipalities were chosen, based on the orientation of their system of production toward the oil palm-based cropping system (Kater, 1993).

5.2.2 Experimental design and land management practices

Data were collected from five different stages of land use at two locations. Within each village, each land use type was replicated twice. As there were no significant differences between both villages, the data were lumped, resulting in five treatments, each replicated four times. The five land use types were:

- Twenty years old fallow (T1);
- Fifteen years old fallow (T2);
- Ten years old fallow (T3);
- Crop rotation fields with maize (in long-rains season) and cowpea (in short-rains season) in association with pruned oil palm less than two m high (T4);
- Monocropping fields with maize (in both seasons) without oil palm (T5).

All cropping fields were in use for around ten years (9-13 years). All fields regularly received organic amendments in the form of household waste, but the amounts have not been quantified. Most fields received mineral fertiliser, indicating development towards more permanent cropping systems. Further information on the cropping fields is provided in Table 4.1.

Table 4.1: Cultural history of the soil of the cropping fields from 2002 to 2010

Treatments	Replicates	Occupation before cropping	Duration under cropping	Cultural rotation		Cultural association		Use of organic amendments and mineral fertiliser	
				LR	SR	LR	SR		
T4	1	*Elaeis guineensis*	10 years	Maize	Cowpea	Maize + oil palm	Cowpea + oil palm	Household waste application	75 kg NPK + 75 kg urea ha^{-1}
T4	2	*Elaeis guineensis*	10 years	Maize	Cowpea	Maize + oil palm	Cowpea + oil palm	Household waste application	No mineral fertiliser
T4	3	*Elaeis guineensis*	9 years	Maize	Cowpea	Maize + oil palm	Cowpea + oil palm	Household waste application	150 kg NPK + 150 kg urea ha^{-1}
T4	4	*Elaeis guineensis*	9 years	Maize	Cowpea	Maize + oil palm	Cowpea + oil palm	Household waste application	125 kg NPK + 125 kg urea ha^{-1}
T5	1	*Elaeis guineensis*	11 years	Maize		No association		Household waste application	100 kg NPK ha^{-1}
T5	2	*Elaeis guineensis*	9 years	Maize		No association		Household waste application	No mineral fertiliser
T5	3	*Elaeis guineensis* + *Acacia auriculiformis*	13 years	Maize		No association		Household waste application	100 kg NPK + 50 kg urea ha^{-1}
T5	4	*Elaeis guineensis*	11 years	Maize		No association		Household waste application	100 kg NPK + 100 kg urea ha^{-1}

LR: Long Rain Season
SR: Short Rainy Season

5.2.3 Assessment of chemical and physical soil quality

Soil Organic Carbon (Walkley & Black method), Nitrogen (Kjeldahl method) and Phosphorus (Bray- I method) were analysed according to the methods in use in the soil laboratory of INRAB (*Laboratoire des Sciences du Sol, Eau et Environnement of the National Institute of Agricultural Research of Benin*) (Saïdou *et al.*, 2009). Four layers were sampled separately and these were bulked: 0-5 cm, 0-10 cm, 10-20 cm, and 20-40 cm. The 0-5 cm sampling was used only for comparison of carbon content with the earthworms casts deposition on top of the soil. For bulk density, in each field four samples were taken. Soil bulk density was calculated as soil dry weight divided by volume (Arshad *et al.*, 1996) with 100g of non-disturbed soil samples.

5.2.4 Plant performance

We set up a pot experiment with these 20 soils (5 land use types x 4 replicates). Soil was collected from 0-20 cm during the rainy season. Maize was planted (one seed per pot)

and grown for 30 days. At the end of the experiment the plants were harvested and dried and root and shoot dry weight assessed.

5.2.5 Assessment of biological soil quality

Density of spores of arbuscular mycorrhizal (AM) was assessed in soil samples of 100 g by wet sieving and decanting (Duponnois *et al.*, 2001). Three layers were sampled separately: 0-10 cm, 10-20 cm, and 20-40 cm.

Arbuscular mycorrhizal colonization was measured on maize roots from the pot experiment from each sample using the gridline intersect method, and 100 intersects were assessed for each sample (Gosling *et al.*, 2013).

Earthworm activity was assessed via earthworm casts (Arnone *et al.*, 2013). We selected four squares (0.5 m x 0.5 m) in each plots. In these small squares, permanently maintained during the investigation, earthworm casts were counted. The same squares were used for soil sampling for chemical and physical analysis. Earthworm casts were counted every ten days, after which they were collected using two spoons (Saïdou *et al.*, 2008). The sampled casts were initially air-dried, sieved (sieve width 2 mm), weighed, crushed, and finally analysed for the determination and comparison of organic Carbon with the 0-5cm soil horizon.

5.2.6 Statistical methods

The statistical analysis consisted of one-way analysis of variance (ANOVA). The factor of analysis was the LUT. Every soil layer was analysed separately. The Student Newman-Keuls test at 5% level of probability was used to determine which treatments were significant from each other, after the ANOVA analysis indicated LUT to be a significant source of variation (Dagnelie, 1998). In this study, error bars represent standard deviation (SD) of means

5.3 Results

5.3.1 Chemical soil fertility

Table 4.2 presents data on organic carbon, nitrogen and phosphorus for the three soil layers (0-10 10-20, 20-40 cm). Analysis of variance showed that there were no significant differences ($P > 0.05$) between the five land use types for carbon, nitrogen and phosphorus at all soil depths. Phosphorus content, especially in the top layer (0-10 cm), was very variable between replicates of the 15-years-old palm fallow, suggesting earlier use of phosphate fertiliser. Phosphorus contents tended to be higher in the top layer of the agricultural fields compared to the oil palm fallows, again suggesting use of phosphate fertiliser.

Table 4.2: Amounts of soil organic carbon, nitrogen and phosphorus in oil palm fallow of different age and in cropping fields

LUT	Carbon (g kg^{-1})			Nitrogen (g kg^{-1})			Phosphorus (mg kg^{-1})		
	0-10 cm	10-20 cm	20-40 cm	0-10 cm	10-20 cm	20-40 cm	0-10 cm	10-20 cm	20-40 cm
T1	8.9±1.7	6.1±1.2	5.0±0.9	0.6±0.2	0.4±0.1	0.3±0.1	5.8±0.8	3.5±0.7	3.8±0.5
T2	10.2±3.2	7.0±1.5	5.4±1.0	0.7±0.2	0.4±0.1	0.4±0.1	24.8±19.8	8.0±4.0	4.3±1.0
T3	7.9±0.4	5.6±0.3	4.2±0.3	0.6±0.1	0.3±0.1	0.4±0.1	7.5±1.6	3.8±0.3	3.3±0.3
T4	7.6±0.3	6.2±0.2	5.5±0.2	0.5±0.1	0.5±0.1	0.3±0.1	13.3±1.6	6.5±1.6	4.5±0.3
T5	7.4±0.8	6.0±0.4	5.2±0.4	0.5±0.1	0.5±0.1	0.5±0.1	10.0±2.1	4.8±0.3	3.6±0.3
ANOVA	n.s.	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

n.s.: ANOVA not significant for land use type

5.3.2 Physical soil quality

There were significant differences ($P<0.05$) in bulk density between land use types (Fig. 4.1). Bulk density was significantly lower in 20-years-old fallows than in maize fields without oil palm and decreased with duration of the fallow.

5.3.3 Plant performance

ANOVA showed that maize root biomass was significantly ($P<0.01$) affected by land use type whereas shoot biomass was not ($P>0.05$; Fig. 4.2). Root biomass was significantly higher in soils from fallows than in soil from maize fields, both with and without oil palm. Shoot dry matter was significantly correlated with amounts of soil organic carbon in the 0-10 cm layers ($r = 0.532$), but this effect was unrelated to differences in land use types.

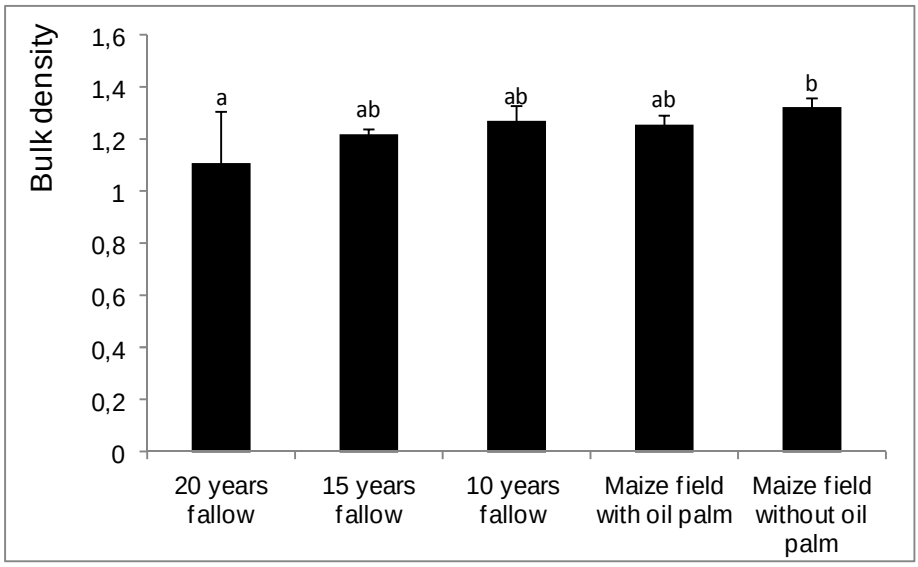

Figure 4.1: Bulk density under oil palm fallow and maize fields

Note: Different letters indicate significant differences between land use types**.**

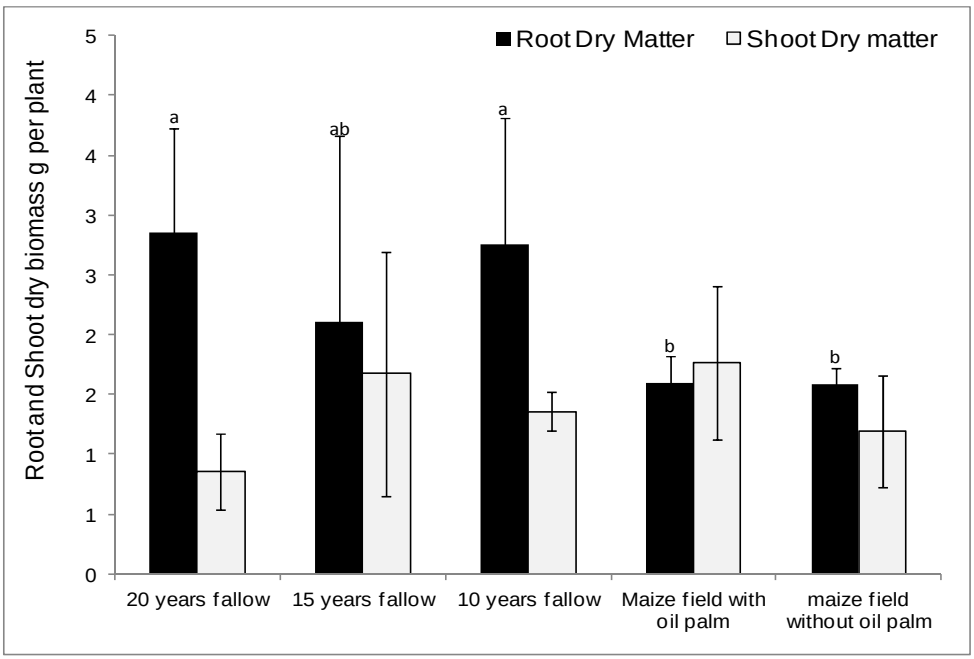

Figure 4.2: Effect of oil palm fallow on the root and shoot biomass

Note : Dry weight of maize grown in pots with soils collected under oil palm fallow (of different age) and maize fields (with and without oil palm). Different letters indicate significant differences in root dry matter between land use types. There were no significant differences between land use types for shoot biomass.

5.3.4 Biological soil quality

Analysis of variance indicated that land use type did not significantly affect number of spores of arbuscular mycorrhizal fungi in all three soil layers. Spore numbers were on average low, between 20 and 50 spores 100 g^{-1} soil (Fig. 4.3). Similarly there were no differences in fractional root colonisation of maize in pots with soils taken from the different land use types. Fractional root colonisation was in the range of 25-30%, with no significant differences between land use types (data not shown).

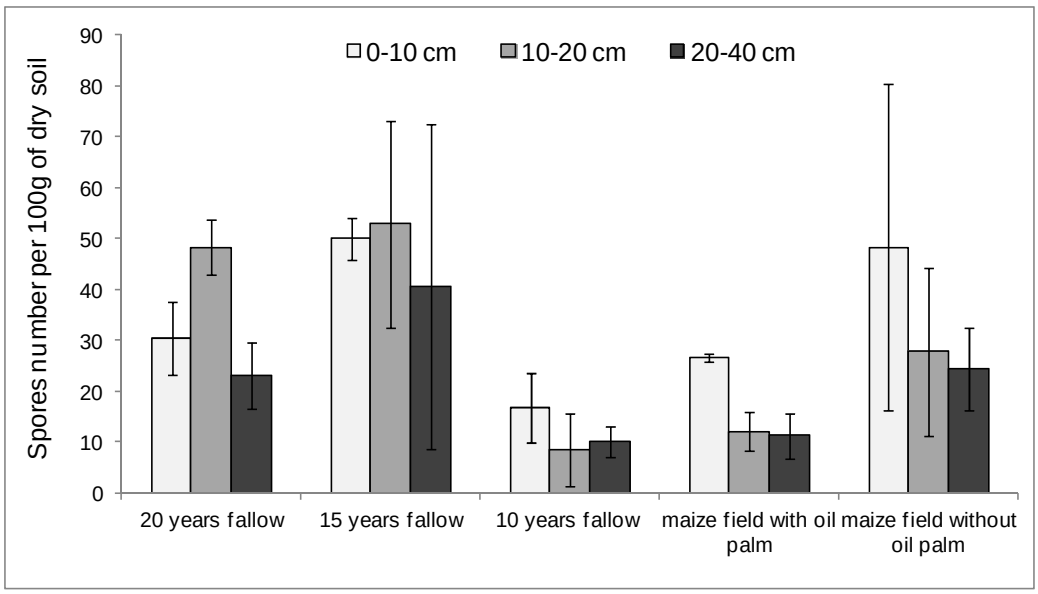

Figure 4.3: Effect of land use types on spore numbers of arbuscular mycorrhizal fungi

Figure 4.4 and 4.5 show the cumulative number of casts per m^2 and the cumulative dry mass of casts in $Kg.ha^{-1}$. Analysis of variance showed that LUT was a significant ($P<0.05$) source of variation. The 20-years-old fallow showed highest number of casts. Cast mass showed a comparable pattern, with cast mass being significantly higher in 20-years-old fallow than in 10-years-old fallow. Earthworm species have not been identified.

Carbon content of casts under different land use types were significantly different, with carbon in casts in 20-years-old fallows being significantly higher than carbon in casts of agricultural fields without oil palm (Fig. 4.6). As soil organic carbon did not differ between land uses (Table 4.2), relative cast enrichment followed the same patterns, ranging from almost 20 $g.kg^{-1}$ in 20-years-old fallow to around 10 $g.kg^{-1}$ (no selective enrichment) in maize fields without oil palm.

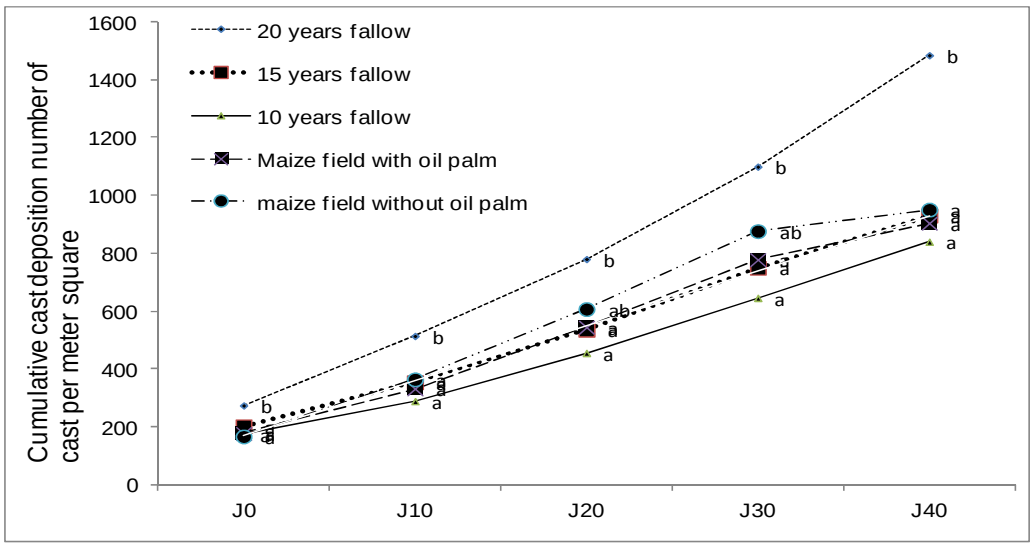

Figure 4.4: Cumulative cast deposition (number of casts per m^2) over time

Note: in the long-rains season in oil palm fallow (of different age) and maize fields (with and without oil palm). Different letters indicate significant differences at every sampling data between land use types.

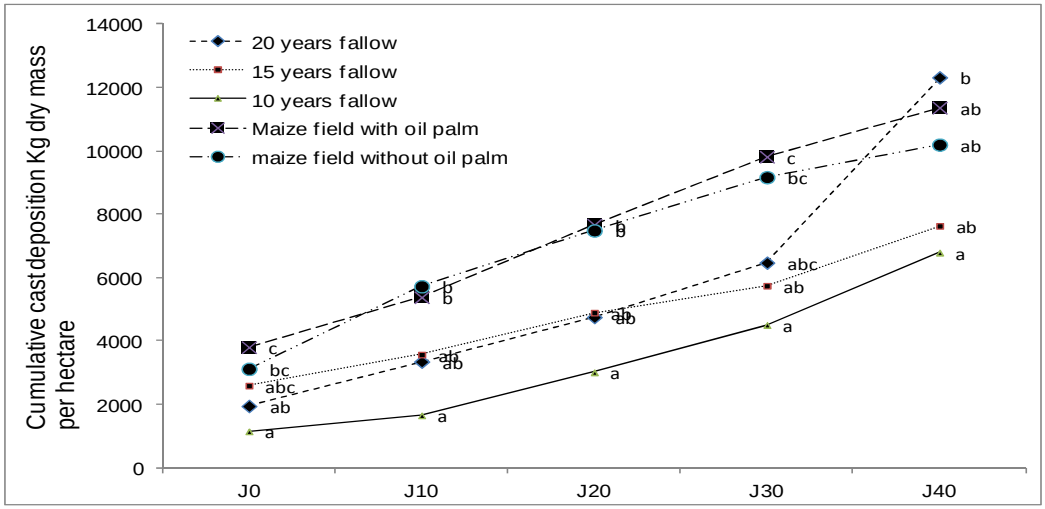

Figure 4.5: Cumulative cast deposition (kg cast dry mass per hectare)

Note: in the long-rains season in oil palm fallow (of different age) and maize fields (with and without oil palm). Different letters indicate significant differences at every sampling data between land use types.

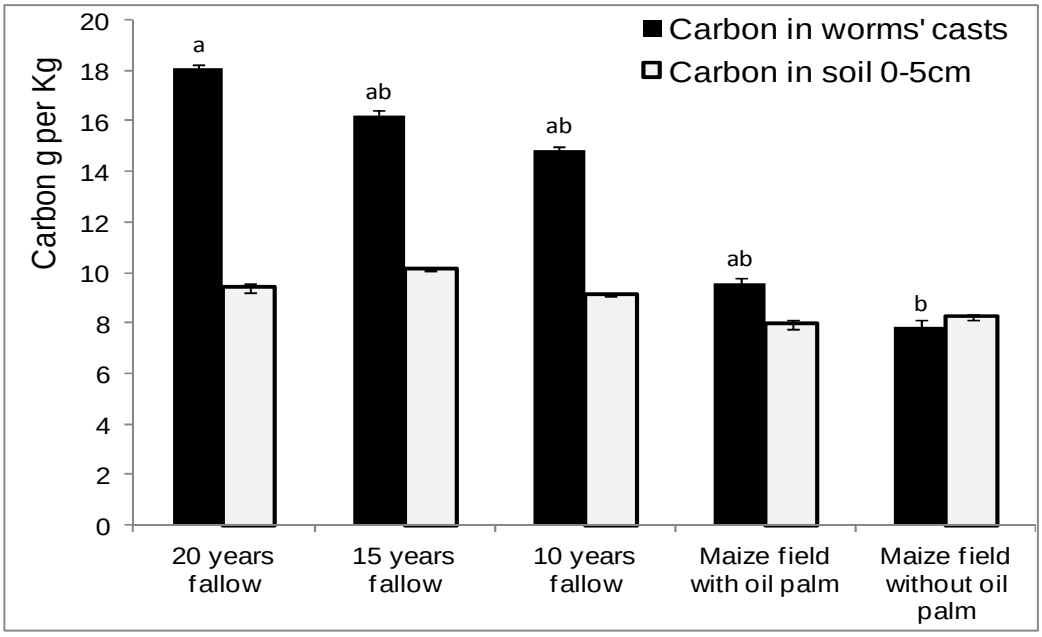

Figure 4.6: Carbon in earthworm casts compared to carbon in soil (0-5 cm)
Note: in the long-rains season in oil palm fallow (of different age) and maize fields (with and without oil palm). Different letters indicate significant differences at every sampling data between land use types.

5.4 Discussion

5.4.1 Role of oil palm fallows in chemical and physical soil quality

Our study did not show any effects of fallowing or fallow length on chemical soil quality, small effects on biological soil quality (earthworm cast number; no effects on arbuscular mycorrhiza) and a significant effect on physical soil quality (where bulk density was lower under fallow and decreased with fallow duration). Lack of significant effects for chemical soil quality are consistent with earlier statements by Brouwers (1993) and Koudokpon *et al*. (1994). Our results also agree with those obtained under palm trees in Ivory Coast (Kabrah and Koffi, 2000). Absolute levels of soil organic carbon and nitrogen were low, partly due to the texture of these soils (high content of sand), but possibly also partly due to soil fertility decline. Our levels of soil carbon and nitrogen were lower than those of soils in plots where oil palm was grown in association with legumes (Adje, 2004). However, a comparative study did not show decreases in soil organic matter levels between 1988 and 1999 in a nearby nitisol near Cotonou (Barthès *et al.*, 2004). It should be noted that farmers on the Adja plateau now regularly use organic amendments (household waste), a practice that was less common at the time when Brouwers executed his research. Possibly cropping intensification has resulted in some investments in soil quality (use of organic amendments, likely also the use of phosphorus fertilisers, to judge from high P levels in some soils of some land use types, Table 4.2). Koudokpon *et al*. (1994) suggested that fallowing improved

physical soil quality (reduction of bulk density) and that suggestion has been confirmed in our study.

5.4.2 Role of oil palm fallows in biological soil quality

Oil palm is dependent on and responsive to mycorrhizal symbiosis (Phosri *et al.*, 2010). However, mycorrhizal fungal spores were infrequent in different land use types at all three soil depths. These values are much below the limit of 5 spores.g^{-1} of soil below which a reduction in maximum root colonization could be expected (Cardoso *et al.*, 2003). Spore density is much lower than those found under *Acacia mangium* and *A. auriculiformis* plantations (2.8 spores.g^{-1} of soil) on ferralitic soil (Sogansa, 2003) and under yam (2-13 spores.g^{-1} soil in the rainy season) in natural savannahs of Benin (Tchabi *et al.*, 2008). A similar study in the centre of Benin yielded 2.6 spores.g^{-1} of soil under *Isoberlinia doka* fallows (Houngnandan *et al.*, 2009), a tree that is also ectomycorrhizal. This difference is possibly due to sampling time as we sampled in the rainy season and spore production is normally increased under conditions of (seasonal) drought (Bohrer *et al.*, 2003).

Earthworms are indicators of soil quality (Guéi and Tondoh, 2012, Tondoh *et al.*, 2013). Many farmers consider cast abundance as an indicator of fertile soils on Adja plateau. While cast number and cast weight were highest in 20-years-old fallows, there was no clear relation between these indicators for earthworm activity and bulk density. In fact, both cast number and weight tended to be higher in agricultural fields than in 10-years and 15-years old fallows. Saïdou *et al*. (2008) observed that cast production was higher in fields with maize and cowpea than in fields with cassava and *egusi* melon, two crops that farmers claimed would increase soil fertility and of which farmers predicted they would have the higher earthworm abundance. Guéi and Tondoh (2012) suggested that earthworm species can be used to monitor the status of ecosystems as some species showed preferences to different land-use types. We noted a lack of correlation between cast number and cast mass, suggesting that different earthworm species were major cast producers in different land use types. However, earthworm species were neither identified to species level nor to the level of functional groups.

5.4.3 Maize productivity in soils under different land use types

We did not observe any significant differences between maize above-ground performance when grown in soils that were collected under different land use types. These results are consistent with the conclusion of Mertz (2002) that a positive correlation between fallow length and yield has not been unequivocally established. Lack of differential crop performance is consistent with lack of effects of fallowing or fallow length on soil organic carbon, nitrogen and phosphorus. However, below-ground biomass of roots was larger under oil palm fallow than in agricultural fields. We hypothesise that this beneficial effect is due to

improvement of soil structure (lower bulk density) as the higher bulk density in agricultural soils would have impeded maize root growth to some extent. Improved soil structure (lower bulk density) may also translate into a better workability of the soil.

5.5 Conclusion: Fallowing and competing claims on land

From a contested agronomy perspective, our results did not provide support for the claim that long-term fallowing is essential for sufficient soil fertility regeneration. A comparison between agricultural fields, where now household waste is regularly added, and oil palm fallow did not show improvement in chemical soil fertility due to fallowing. The period of ten years fallowing did not result in poorer soils than a period of twenty years fallowing. Further shortening of the fallow is not likely as the palm trees need time to grow after pruning ends to become what seems like an oil palm plantation. It may be possible that fallow length impacts on the quantity and quality of the *sodabi* produced, when the trees are felled, but we did not address that question. The fact that the practice of long-term fallowing is not as crucial as claimed by landowners may be related to observations that the oil palm fallow is gradually disappearing from the Adja plateau, likely driven by processes of agricultural intensification and commercialisation (see Chapter 3). Our data therefore confirm our earlier conclusion (Yemadje *et al*., 2012) that it is more enlightening to evaluate the oil-palm based cropping system from a political ecology view than from an agroforestry point of view. All indicators show that the practice of oil palm fallowing is less an agronomic technique than a dynamic arena where landowners and tenants struggle over control over and access to land, and where the length of the fallow duration is part of a strategy through which landowners react to cropping practices of tenants. However, with increasing commercialisation and intensification of agriculture, agricultural practices continue to change (increased use of mineral fertiliser, use of organic amendments), as do the nature of contracts between landowners and tenants. These socio-economic changes are now driving the demise of the oil palm-based cropping system on Adja as it is slowly being replaced by more permanent systems (Chapter 3).

Chapter 5

Evaluating the combined effect of organic amendments and mineral fertiliser on maize productivity, soil organic carbon and earthworms dynamics on the Adja plateau, Benin

Abstract

There is uncertainty about how the combined mineral fertiliser and organic matter application improves soil organic carbon (SOC) and crop productivity. In this study, we investigated the combined use of mineral fertiliser (EC) 200 kg ha^{-1} and a local endogenous practice, household waste application, (OM) in one gift of 15 t ha^{-1} or 30 t ha^{-1} 17 months before the harvest. Data were collected on (1) maize performance (grain, stover, N and P uptake and mass fraction, N:P ratio) and (2) SOC contents, and earthworms dynamics). Maize grain yield was increased by both fertiliser and household waste. However, the effect of organic amendments was much stronger. A single dose of household waste doubled grain yield 17 months after application (from 706 to 1559 kg ha^{-1}) and a double dose trebled yield (to 2198 kg ha^{-1}). Yield increases due to mineral fertiliser of the crop to which the fertiliser was applied varied between 300 and 500 kg ha^{-1}. The combination of mineral fertiliser with organic amendments had a significant synergy effect on stover. However, there was no significant synergy effect for the combined organic matter and mineral fertiliser for earthworms' casts, SOC, nutrient uptake and grain yield. We conclude from the study the need to promote quality and quantity of the household waste practice for soil quality and food crop performance improvement.

Keywords: mineral fertiliser, contested agronomy, earthworms, political ecology, organic carbon

6.1 Introduction

The role of soil organic matter (SOM) in integrated soil fertility management (ISFM) and its possible importance for sustainable agricultural intensification has been extensively studied. Authors have addressed the advantages of an integrated approach, combining organic amendments with mineral fertiliser as an effective way of increasing agronomic efficiency of those mineral fertilisers (Bationo and Buerkert, 2001, Reij and Waters-Bayer, 2002, Chivenge *et al.*, 2009, Vanlauwe *et al.*, 2011). Increased agronomic efficiency of fertiliser could be especially important in Africa, where availability of fertiliser is often low and costs are high, two to eight times higher than in the rest of the world (Bationo *et al.*, 2007). In that regard, quality and quantity of organic resources for use as soil amendment are crucial.

On the Adja plateau in south-western Benin, organic resources in the form of household waste (Wartena, 2006) and mineral fertilisers are applied in agricultural fields. Currently, the use of fertiliser seems to be increasing as part of a process of agricultural intensification and commercialisation (Chapter 3). During that process the oil palm fallow, which is part of the oil palm-based cropping system, (OPBCS: Brouwers, 1993, Koudokpon *et al.*, 1994) is gradually declining in frequency and in duration. The OPBCS is a system where long-term oil palm fallows are alternated with long-term cropping on land with oil palms. Cropping, under rental arrangements, is allowed as long as palm trees remain lower than two meters high, inducing tenants to severely prune oil palms to inhibit growth. Consequently, landowners prefer long-term fallowing (more than ten or twenty years), even though the benefits for soil quality are minor (Chapter 4).

Organic matter contributes to plant growth through its effect on physical, chemical, and biological soil quality. It provides nutrients, especially nitrogen (N), phosphorus (P) and sulphur (S) to plants. It also affects soil porosity and soil structure, creating a more conducive environment for root growth and also a better workability of soils (Pol van der, 1993, Smaling *et al.*, 2002). Effects on chemical and physical properties are due to the activity of soil biota, ranging from microbes (bacteria, fungi; chemical engineers) via micro and mesofauna (nematodes, springtails; biological regulators) to macrofauna (earthworms, termites; ecosystem engineers). Organic matter is therefore a key indicator for soil quality. Soil organic matter decline is associated with soil degradation, and may set a spiral of further negative effects into motion (Lal, 2008). Chivenge *et al.* (2009, 2011b) reviewed research on the use of organic resources in cropping systems on various African soil types. When applied singly, that is without mineral fertiliser, organic resources can increase crop growth, especially if organic resources are of high quality, showing low C:N ratio, and low concentrations of lignin and phenolics (Palm *et al.*, 2001, Vanlauwe *et al.*, 2011). Organic matter amendments also increase use efficiency of mineral fertiliser (Mokwunye *et al.*, 1996, Braun *et al.*, 1997, Smaling *et al.*, 2002); the magnitude of this effect varies between soil types.

Soil biota are central contributing components of soil fertility (Zombre, 2006). The occurrence of certain soil organisms is also used as an indicator for soil quality. Farmers in Africa regard earthworms as indicators of soil fertility (Henrot and Brussaard, 1997, Saïdou *et al.*, 2008). The contribution of earthworms to soil fertility is due both to chemical mechanisms (enhanced breakdown of organic matter, increased mineralisation of nutrients, accumulation of nutrients in casts) and physical mechanisms (porosity, aggregate stability). Consequently, monitoring earthworm activity in a study on the effects of organic amendments (alone or in combination with mineral fertiliser) might help to better understand the role of organic resources in soil fertility and crop productivity.

This study investigated the role of a specific organic resource, household waste, on soil quality and crop productivity on the Adja plateau. The principal research questions were: what are the effects of household waste application on (1) soil organic carbon, (2) maize performance (yield, nutrient uptake); (3) casting activities of earthworms. We report here on the results of a farmer-managed experiment over a period of 23 months.

6.2 Materials and methods

6.2.1 Study site

The study was conducted on the Adja plateau, located in the oil palm belt in south-western Benin, 230 km north-north-west from Cotonou. The fields at Akouegbadja village are located between 6°56' 09" and 6°59'56" N and between 2°53'21" and 1°55'20" E. Average annual rainfall on the plateau is up to 1100 mm annually (900-1200mm). Rainfall is very variable, both spatially and temporally (Amoussou *et al*., 2009). The climate is sub-equatorial with bimodal rainfall with two rainy and two dry seasons. The soils are *sols ferralitiques de dominance rouge* classified as Nitisols (*terre de barre*; sandy to sandy-loam soils), according to the FAO soil classification and as Eustrustox, (USDA soil taxonomy) (Azontonde, 2000).

The experiment was carried out during two consecutive years (four cropping seasons) to investigate performance of a maize crop, change in soil organic carbon (SOC), and earthworm casting on farmer plots in Akouegbadja. Both landowners and tenants participated in the experiment. Landowners and tenants set the objectives of the research and demonstrated willingness to cooperate.

6.2.2 Experimental design and plot establishment

Information on the major constraints to soil fertility and yield decline were collected through focus group discussions (FGDs) and individual in-depth interviews (Yemadje *et al.*, 2012). In Chapter 2 we saw that different categories of farmers (landowners, male tenants, female tenants) identified different constraints. This trial was an initiative of the main researcher and was designed and implemented in collaboration with farmers from the community. I took into account the influence of gender roles in agriculture and land

ownership on participatory technology development (Pircher *et al.*, 2013). Subsequently, the trial participants have been selected randomly.

Together with the village chief, we generated the list of heads of household of the Akouegbadja village. During a first village meeting, we randomly selected 10 heads of household to invite to participate in the experiment. Next, each of head of household chose one participant inside his household to conduct the experiment. The group comprised 3 women and 7 men while 2 men dropped out before the end of the first cropping season. The three women rented land from their husband, whereas the 5 men owned the field.

During the first village meeting, and based on what the group members jointly regarded as the major constraints (problem of soil fertility recovery rate), during the first village meeting we agreed to test and evaluate the the combined effect of organic amendment and mineral fertiliser. Consequently, responsibilities for implementing the experiments were discussed during the workshop. The agreement was that the main researcher would provide NPK and urea fertiliser, and seed while participating farmers would provide land, household waste and labour. All farmers decided to set up a factorial experiment with organic resources (household waste: absent, or applied in two different amounts) and mineral fertiliser (applied or not). The treatments were as follow:

- Control (C), without organic amendments or mineral fertiliser
- Mineral fertiliser only (EC)
- Single dose of household waste application without mineral fertiliser (1OM)
- Single dose of household waste application with mineral fertiliser (1OM+EC)
- Double dose of household waste application without mineral fertiliser (2OM)
- Double dose of household waste application with mineral fertiliser (2OM+EC).

In all, eight farmers participated in the experiment. Household waste was applied by farmers from their own waste, implying some variation in organic matter quality. Household waste in Akouegbadja village consists mainly of cowpea pods and peanut shells (70%) with some remains of maize. Household waste is collected in special containers containing around 100 kg of organic waste when filled. Due to limited availability of land and of insufficient availability of household waste, four farmers applied a single dose and four a double dose (Table 5.1) on individual plots, which were 67 m^2. The comparability of the single and double dose treatments from plots to plots has been maintained. Application rates were 15 and 30 tonnes household waste per hectare respectively. The control treatment was applied by all eight farmers, as well as the fertiliser treatment (Table 5.1).

The experiments were conducted from the beginning of the short cropping season in 2010 (August/September) to the end of the long cropping season in 2012 (July) and covered in total two short and two long cropping seasons. Maize was grown in the long cropping season and cowpea (local variety) in the short cropping season. Maize was planted using two seeds per plant hole at an inter and intra-row spacing of 80 cm and 40 cm, respectively. NPK

(150kg ha^{-1}) and urea (50kg ha^{-1}) fertiliser were applied at 25 and again at 45 days after sowing in the first and the second cropping seasons. Household waste was only applied to the plots in the beginning of 2011, before the start of the long rainy season (long cropping season). The farmer group agreed to meet regularly every three months from September 2010 to November 2012 to analyse outcomes and past activities and to plan future meetings.

Table 6.1 Matrix of experimental treatments

Farmer	(0, 0)	(0, 1)	(0, 2)	(1, 0)	(1, 1)	(1, 2)
1	X	X	-	X	X	-
2	X	-	X	X	-	X
3	X	-	X	X	-	X
4	X	X	-	X	X	-
5	X	X	-	X	X	-
6	X	-	X	X	-	X
7	X	X	-	X	X	-
8	X	-	X	X	-	X

Note: (EC, OM). EC 0 or 1 implies absence or application of mineral fertiliser; OM 0, 1, 2 imply absence of organic amendments or application of amendments in single or double dose.

6.2.3 Soil sampling and analysis

Soil samples, 0-20 cm, were collected systematically in four permanent subplots of 0.50 m x 0.50 m of each treatment, and subsequently bulked. In all, there were 32 soil samples. Samples were air-dried and passed through a 2 mm sieve for the assessment of soil organic carbon (Walkey-Black) and nitrogen (Kjeldahl) and phosphorus (Bray-I). Methods are those in use of Benin's national soil lab INRAB (Saïdou *et al.*, 2009).

Earthworm activity was assessed in four subplots of 0.50 m x 0.50 m of each treatment (the same 4 plots as for the soil samples). Data from all four subplots were lumped. In these subplots, permanently maintained during the investigation, casts were counted and collected every fifteen days (Saïdou *et al.*, 2008). We did two rounds of assessment. One in 2011 and a second in 2012. In 2011, the first assessment took place two months after the organic amendment application and 15 months later (in 2012), the second round of assessment took place. Casts were air-dried, then oven-dried at 40º C, before weighing.

6.2.4 Crop yield

Grain yield of a 4 m² area (installed inside the sub-plots under each treatment) was measured three months after sowing, during the long-rainy season. Again subplot yield data were lumped (yields from all the plots under the same treatment). Data were collected on stover (stem, leaf), and grain weight. Plant material was oven-dried at 75 º C for 72 hours and then weighed. Data were converted into kilogram (kg) of dry matter per hectare. Nitrogen content of grains and stover were determined by the Kjeldahl method. Total phosphorus was

determined by dry ashing a plant sample in a muffle furnace a 550 º C for 4 hours and gathering the residues in 1N HNO_3 involving a period of heating. P was then subsequently measured colorimetrically by ammonium molybdate with ascorbic acid at a wavelength of 660 nm.

6.2.5 Statistical analysis

The experiment was set up as a factorial experiment with two factors (application of mineral fertiliser; application of household waste). Due to constraints that farmers faced in the availability of household waste, the design was unbalanced (Table 5.1). Inspection showed that the soils of the trial plots of the farmers who applied a double dose of household waste were only insignificantly more fertile with higher amounts of organic carbon and nitrogen than the plots of the other participating farmers. Data analysis therefore followed 2-way ANOVA with missing values without replacement.

Inspection of the data obtained from the lab and related to data collected in 2011 (grain N and P, grain yield) could not allow much conclusion and presented several problematical outcomes. Data analysis was therefore restricted to the data collected in 2012 for maize productivity, SOC, soil N and P.

For earthworms, two-way analysis of variance (ANOVA) was executed both for 2011 and 2012 casts counted. If the F value was significant ($P<0.05$), differences between treatments were assessed using the Student Newman-Keuls test at 0.05 level.

6.3 Results

6.3.1 Maize crop response to differential fertilization

The results of crop performance are shown in Table 5.2. All parameters (except N:P ratio) were significantly affected by application of mineral fertiliser. Organic amendments also affected most parameters, except grain P mass fraction and N:P ratio. The interaction between mineral fertiliser and organic amendments was only significant for stover yield but for none of the other factors.

Stover yield was increased by both fertiliser and household waste (Table 5.1 and Fig. 5.1). Grain yield was equally increased by both factors. However, the effect of organic amendments was much stronger. A single dose of household waste almost doubled grain yield (from 706 to 1559 kg ha^{-1}) and a double dose trebled yield (to 2198 kg ha^{-1}). Yield increase due to mineral fertiliser varied between 300 and 500 kg ha^{-1}. Nitrogen and phosphorus uptake followed the same pattern, with a stronger effect for organic amendments than for mineral fertiliser. Plant N:P ratio did not change as a consequence of either fertiliser or organic amendments. Nitrogen mass fractions increased due to mineral fertiliser, indicating some luxury N uptake. Mineral fertiliser also resulted in some P luxury uptake. However, the difference between the individual treatments was not significant.

Table 6.2: Effect of application of mineral fertiliser and organic amendments

	stover	**grain**	**N**	**P**	**N**	**P**	**N:P**
	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(g kg^{-1})	(g kg^{-1})	
control	868^{b}	706^{d}	12.1^{c}	1.8^{c}	17^{ab}	2.3	8.2
EC	968^{b}	1119^{cd}	21.5^{c}	3.3^{bc}	19^{a}	2.9	6.9
1OM	913^{b}	1559^{bc}	22.1^{c}	3.7^{bc}	14^{b}	2.4	6.1
1OM+EC	1786^{a}	2085^{ab}	36.3^{b}	5.7^{ab}	17^{ab}	2.8	6.3
2OM	1576^{a}	2198^{ab}	36.6^{b}	4.4^{abc}	17^{ab}	2.0	8.7
2OM+EC	1895^{a}	2508^{a}	53.6^{a}	6.5^{a}	22^{a}	2.5	8.8
ANOVA							
EC (df = 1)	17.5***	5.7*	22.6***	12.3**	10.1**	6.6**	0.5
OM (df = 2)	23.2***	27.6***	37.0***	12.6***	3.6*	1.1	3.1
EC * OM (df = 2)	4.9*	0.1	0.7	0.1	0.8	0.0	0.5

Note: EC: application of mineral fertiliser, OM: application of household in single or double amount (1OM, 2OM). Different letters indicate significant differences (Student Newman-Keuls test at $P < 0.05$). ANOVA data indicate F values. * $0.01 < P < 0.05$; ** $0.001 < P < 0.01$; *** $P < 0.001$.

Left: Maize grown on control treatment without organic amendment or mineral fertiliser

Right: Maize grown on double dose of household waste application with mineral fertiliser

Figure 6.1: Maize stover as affected by application of mineral fertiliser and organic amendment

6.3.2 Soil organic carbon (SOC)

Soil organic carbon did not significantly change due to addition of mineral fertiliser or of organic amendments. Organic carbon increased with around 15% with the application of a double dose of household waste (from 6.5 to 7.5 g kg^{-1} soil), but this increase was below the level of significance. Also, after accounting for initial differences in fertility of the soils of the different farmers (see material and methods), the effects of organic amendments and mineral fertiliser on soil organic carbon were not significant. Mineral fertiliser had no effects on SOC. Organic nitrogen also did not significantly change (data not shown).

6.3.3 Earthworm activity

Earthworm cast number and cast mass increased linearly over time during the first rainy season in both 2011 and 2012. ANOVA indicated that cast number was significantly affected by organic matter amendment in 2012, but not in 2011. In 2011, it was higher in treatments with household waste than in treatments without household waste (Table 5.3). Mineral fertiliser and the interaction between organic amendments and mineral fertiliser did not significantly impact cast number. Earthworm activity was at all times lowest in the control and in the EC treatment. Cast mass and number in 2012 followed the same pattern (Table 5.4). It was lowest in the plots without organic matter amendments (control and EC). Doubling the amount of household waste applied did not have further effects on cast mass. After application of organic amendments, casts mass more or less doubled (from 4.1 to 8.7 t ha^{-1}).

Table 6.3: Analysis of variance (F-value) of cast deposition per meter square in 2011-2012

Year		2011				2012			
Source of variation	df	0	15	30	45	0	15	30	45
EC	1	0.246	0.521	0.632	1.130	0.312	0.256	0.056	0.140
OM	2	9.441**	2.253	1.619	0.978	0.432	1.224	2.953	5.545*
EC*OM	2	0.131	0.107	0.249	0.178	1.239	1.058	0.430	0.272

Note: Observations started 2 months after household waste application to the plots. F-value in parenthesis (symbols for significance levels: *p<0.05; **p<0.01; all other values are not-significant).

Table 6.4: Analysis of variance (F-value) of cast cumulative dry mass in 2012

Year		2012			
Source of variation	df	0	15	30	45
EC	1	0.085	0.090	1.208	3.703
OM	2	2.311	6.174**	9.123*	17.544***
EC*OM	2	0.088	0.035	0.010	0.129

Note: Observations started 2 months after household waste application to the plots. F-value in parenthesis (symbols for significance levels: *p<0.05; **p<0.01; ***p<0.001 all other values are not-significant).

6.4 Discussion

6.4.1 Experimental design

The experiment was set up in collaboration with farmers. They proposed treatments with household waste (two different amounts) with and without combining it with mineral fertiliser. They also provided fields where the experiments took place. However, due to

limitations of amounts of household waste available, farmers either experimented with a single dose or a double dose. Although the farmers' self-selection for the single-dose or the double-dose sub-sample was probably not random, our soil data from 2010 (before the experiment) and 2012 (control treatments) suggested that farmers who applied a double dose of household waste had only slightly more fertile fields with higher contents of soil organic carbon and total nitrogen than those who applied a single dose; the difference was too small to be significant. Also soil fertility was not different at the start of the experiment between the men who owned the land and the women who rented the land from their husband. In order to take that potential bias into account, we analysed data with two different methods. We applied two-way ANOVA with missing values on the yield data for 2012 (the yield data for 2011 almost certainly contained errors in the calculations of N and P and hence in N:P ratio). We also calculated a response ratio (the natural logarithm of the ratio between organic carbon in 2012 and 2010) and applied two-way ANOVA afterwards. Both methods yielded similar results (no significant differences in changes in soil organic matter between the groups of farmers and hence no differences in yield due to intrinsic soil fertility), due to larger variation between individual farmers than between the groups of farmers who applied a single and a double dose of household waste. Each farmer produced his own household waste and incorporated it into his/her soil before we could test for any intrinsic differences between the qualities added. Depending on the farmers' livelihood activities, the composition of the household waste could differ slightly. Women sweep the compound and process agricultural products and tend to have easier access to better quality waste. Livestock holders have access to their manure, farmers who cultivated and/or processed particular products have access to their residues, and those who have trees in plantations or in their compound may bring the litter to their fields. However, from discussions with farmers it was likely that the composition of the waste used in the experiment was comparable between farmers; therefore small differences have not been taken into account.

6.4.2 Changes in soil properties and yield

Our soils were characterised by low contents of soil organic carbon (around 7 g C kg^{-1} soil). The changes after addition of household waste (one-time addition; the material was easily decomposable and relatively rich in nitrogen) were expected to be minor. We observed no significant changes (a non-significant increase of 2 and 15% respectively with single and double dose of household waste), fitting with our expectation. The question remains, though, whether the low contents of soil organic carbon and nitrogen indicate serious soil fertility decline on the Adja plateau (due to crop intensification without adequate nutrient replenishment), or whether soil texture is the main cause for low soil organic carbon and nitrogen contents. In that latter case the build-up of more soil organic matter would be very difficult, considering the limited amounts available. The observation that some farmers were

able to generate more household waste for their experimentation than others would be consistent with the possibility that different fields reflect decline and / or recovery of soil organic carbon to different degrees. However, an earlier study by Azontonde (2000) also showed low levels of organic carbon, especially in the most sandy soils. Similarly a study by (Barthès *et al.*, 2004) in a comparable nitisol (close to Cotonou) did not provide evidence for any significant soil fertility decline between 1988 and 2000. We consider it therefore more likely that initial differences in soil organic carbon contents relate to differences in soil texture than to differences in the degree of soil fertility decline. Farmers in Akouegbadja also believe that soil fertility disappears when the soil's clay fraction erodes (Wartena 2006: 505). Studies by Kerkdijk, presented in Wartena (2006: 658-663) and Brouwers (1993: 77) indicate a relation between history of cultivation and soil texture on the one hand and SOC and soil organic matter on the other. Unfortunately, data on soil texture for the eight plots are not (yet) available. (Plante *et al.*, 2006) suggested as well that soil texture affects soil C stocks. Our study also corroborates results from central Benin obtained by (Acakpo, 2004), who worked on carry over effects by cotton cultivation for soil fertility for subsequent maize growth.

Yield significantly increased after application of mineral fertiliser and especially organic amendments. However, there was no significant interaction, indicating that addition of household waste (and potential changes in soil organic matter) did not (yet) affect agronomic use efficiency of fertiliser (at least not when studying the effect after roughly 17-18 months of a single gift of household waste). Nutrient uptake followed grain yield with also larger effects for organic amendments than mineral fertiliser. These data confirm that the farmers' household waste consists of high-quality organic material with immediate effects on soil fertility. Therefore, this data supports the claims and actions of many farmers of the learning group who state that fertiliser is useless if you can lay hand on sufficient volumes of household waste.

In addition to the agronomic implications, these results also have implications on social organization of land management, particularly choices by tenants for fertiliser and/or organic amendments. When tenants use land under sharecropping arrangements (*deman* in Adja language), the relative distribution of the harvest depends on whether or not the landowners provide mineral fertiliser (Yemadje *et al.*, 2012). Standard sharecropping practice in Akouegbadja is for the tenant to keep two-thirds of the harvest and for the land owner to receive one-third. However, if the landowner provides mineral fertiliser, the yield is split 50/50. So, in principle, yield increases should outweigh the changed terms of the arrangement. In our study, yield increases due to mineral fertiliser at the studied dose of 200 kg ha^{-1} were around 300-500 kg ha^{-1}. Local fertiliser prices during the study period were 16000 FCFA per bag of 50 kg. Without household waste, application of mineral fertiliser is beneficial for tenants (their share increases from 471 to 560 kg ha^{-1}) if the price of maize is at least 360 FCFA kg^{-1}, the costs of additional labour due to fertiliser application and interest not taken

into account. However, in the presence of household waste, the provision of mineral fertiliser is rather disadvantageous for sharecroppers (with single dose there is no difference in share; with double dose an effective reduction from 1465 to 1254 kg ha^{-1} while in both cases fertiliser has to be paid). This effect is due to the fact that with household waste and fertiliser only half of the yield increase goes to the tenant, while in the absence of fertiliser this would be two thirds. These arrangements therefore explain limited interest in mineral fertiliser application by both sharecroppers and landlords in sharecropping arrangements compared to the use of household waste. It also explains why landlords value sharecroppers who apply household waste – landlords do not contribute to waste application costs or efforts but do share in the benefits. The results also show that with the current fertiliser price of 16000 FCFA per 50 kg, its application on maize by landlords who farm their own land is beneficial when the price of maize is at least 128-213 FCFA kg^{-1}, interest and additional labour due to fertiliser application not taken into account.

However, N (and partly P) mass fractions were more affected by mineral fertiliser than organic amendments, indicating luxury uptake. The grain N:P ratio varied between 6 and 8 (Table 5.2). These values are slightly higher than maize grain N:P ratios reported by (Saidou *et al.*, 2003), who reported an N:P ratio of 5.3 for *terre de barre* soils (Nitisols) in southern Benin. Our data agree more with the optimal N:P ratio for hybrid maize (7.8) as proposed by (Janssen *et al.*, 1994).

The farmers evaluated the effects of mineral fertilisers and organic amendments performance based primarily on the maize response. In a study in Malawi (Kamanga *et al.*, 2013) similar criteria for farmer evaluation of different types of fertilisers have been used. Farmers described main criteria for evaluating regenerated soil fertility for their cropping systems. Overall, farmers' main criteria for evaluating a soil fertility were the colour of maize leaves, the height of maize plants, thickness of the maize pad and stover, and finally the presence and density of earthworms casts. Female and male participants unanimously agreed on the combined application of organic amendment and mineral fertiliser as the best practice. They also noted that mineral fertiliser only, had an effect on biomass of stover (which is not their desire) while organic amendment made maize grain more consistent and robust.

6.4.3 Impacts on earthworms

The numbers of casts were higher in 2011 than in 2012, indicating a higher activity of earthworms in 2011 than in 2012. This difference is due to the one-time application of household waste, early in 2011. After one year, most of the material was probably decomposed. Addition of fresh organic matter promotes the activity of earthworms (Jordan *et al.*, 2004). It would therefore be essential to annually apply some waste to the fields in order to maintain increased earthworm activity. However, relative differences between treatments remained the same, with a positive effect for addition of household waste and a slight

negative effect after application of mineral fertiliser. Studies showed that during composting, the decomposition of organic resources that received nitrogen was faster than those in a control without nitrogen (Sérémé and Mey, 2008), which might explain the negative effect of nitrogen on earthworm activity.

Authors have investigated the role of biota in the soil organic carbon stock and shown the usefulness of earthworms in the transformation of organic matter (Pulleman *et al.*, 2005, Ernst and Emmerling, 2009). Farmers in the learning group linked improved soil fertility in general to the presence of earthworm casts on the field. They also could judge that casts of different sizes indicate different soil properties. At the end of the experiments, farmers ranked mineral fertiliser and organic amendments and linked organic amendment to large size of casts. They are aware that fewer but larger sized casts were found on more fertile soils and numerous smaller casts on poorer soils.

6.5 Conclusion

These results imply a relevant message for agriculture in the face of intensification and commercialisation on the Adja plateau. Tenants involved in sharecropping on the studied part of the Adja plateau give one third of the harvest to the landowner, but when the landowner cooperates and provides mineral fertiliser, the terms of the arrangement in the study area change and half of the harvest goes to the landowner (Yemadje *et al.*, 2012), which explains the limited interest of sharecroppers in sharecropping arrangements in mineral fertiliser application as compared to the use of household waste. This study shows that while landowners in sharecropping arrangements (who can supply half of the mineral fertiliser) may cooperate with their tenants (who can apply their household waste), the synergy effect between the two sources of fertilisation could not be shown to be significant except for their effect on stover. It also shows that interests of both groups in the sole or combined use of both household waste and mineral fertiliser are still somewhat divergent. Under the specific sharecropping arrangements in the study villages, sharecroppers only benefit from mineral fertiliser application if no household waste is applied, while their landlords benefit from their sharecropper's application of waste irrespective of mineral fertiliser. This knowledge should be useful in proposing solutions that contribute towards a win-win cropping system. Since investing in a mix of both household waste and mineral fertiliser does not show an interaction effect (i.e., no higher agronomic use efficiency). We recommend the provision of quality and quantity of household waste for soil quality and food crop performance. Furthermore, sharecropping arrangements should be changed in such a way that sharecroppers who apply waste are either supported or rewarded for this by their landlord. A possible way to reach the same goal of promoting quality and quantity of organic matter (household waste) is integration in the new paper contracts (which allow tenants' cropping up to 25 years) of the necessary use of household waste on the rented land (Chapter 3).

Chapter 6

General Discussion and Synthesis

7.1 Introduction

My thesis addressed the following research questions: (a) What are the constraints and opportunities for landowners and tenants with regard to soil fertility management practices in the oil palm-based cropping system (OPBCS) on the Adja plateau? (b) How does land titling affect conflict (and conflict resolution) between different landowners who claim the same plot? (c) How does land titling affect conflict (and conflict resolution) between landowners and tenants with regard to access to land for cropping purposes? (d) How does land titling and land access regulation affect soil fertility management practices by landowners and tenants? The research took place on the Adja plateau, an area where this oil palm-based cropping system was described as a form of sustainable soil fertility management (Brouwers, 1963; Koudokpon *et al*., 1994) and therefore as a basis for the intensification of oil palm production, a priority of the Beninese government. It became clear at the start of my project that this land use system was more complex than just a form of sustainable land management; and that responses of landowners and landless tenants on the Adja plateau needed to be understood in relation to contested claims how soil fertility was actually managed (during cropping cycles) and on how it should be managed in the long term (in relation to fallowing).

The overall objective was to understand how changes in land ownership and changes in access rules shape (changes in) soil fertility management practices and outcomes. Changes in land tenure and soil fertility should be recognised as potentially separate issues and therefore both existing (and possible future) property and use rights (customary *versus* formal) in relation to cropping practices were studied. The natural experiment studied (the land titling programme) was implemented in some villages on the plateau, whereas other villages nearby were not part of that programme. This general discussion builds upon a political ecology framework and highlights cross-cutting issues in the findings.

7.2 Main findings of my study

Competing claims over land

My project started with a diagnostic study where I investigated the social and agro-ecological dynamics of the OPBCS (Chapter 2). I intended to use the outcomes of the diagnostic study to explore options in soil fertility management on the Adja plateau in the face of increasing agricultural intensification. The study documented know-how (including knowledge and practices) of both landowners and tenants and tried to understand options for sustainable intensification through both technical and institutional lenses. The study showed that growing oil palm for palm oil production was very rarely the main reason for the existence of the OPBCS. Landowners rather used the oil palm trees to produce *sodabi,* claiming at the same time that when the land is covered by mature oil palm without managed food crops below soil fertility restoration takes place. Tenants, who do not have the right to

plant oil palm, access land with scattered juvenile oil palms. They can crop food crops as long as the oil palm is less than 2 m high. By severe palm frond pruning they try to prevent palm trees from reaching that critical height, thereby extending their cropping period. This results in extended cropping periods (up to decades), and when finally palm trees reach that critical height, landowners respond by equally long fallows. What seemed at the outside, and especially to earlier observers, a sustainable and innovative agroforestry system, turned out to be at the same time an arena for struggle over control of land, with both parties trying to maximise the period they can exert control over the land, using a discourse of soil fertility decline and regeneration. These competing claims apparently coexist because of overlapping institutions (customary and formal) that shape access to and use of the land. The question was then raised to what extent the system can remain stable in the face of external drivers on the Adja plateau (agricultural intensification, commercialisation, changing government policies and state interventions) or to what extent institutional transformations are needed to develop new strategies for sustainable soil fertility management that are attractive for both landowners and tenants, and hence transform the OPBCS from a zero-sum game to a win-win situation.

In Chapter 3 I made use of an external intervention that provided a kind of natural experiment. A land-titling intervention took place in some villages on the Adja plateau, whereas other, seemingly similar villages did not participate in the titling intervention executed under the responsibility of MCA-Benin (Chapter 3). This natural experiment therefore allowed me to test relations between titling and soil fertility management. The results of my study showed two consecutive processes, which were caused by the fact that the initial outcomes of the titling created problems that subsequent reforms tried to address. In the first phase land registration resulted in increases in a modern legal land system with ownership titles. In order to demonstrate authority over land, land owners chased off tenants, thereby increasing tension over land access between owners and tenants. A second step remedied that tension by arranging new contractual forms between landowners and tenants for land use. I observed evidence of conflict reduction between landowners themselves and between landowners and tenants. Reduction of tension and conflict resulted in increased willingness to invest in soil fertility, shown by increasing use of mineral fertiliser but not, contrary to expectation, of organic amendments. I also demonstrated a faster demise of the OPBCS after the MCA intervention, but even in the non-MCA village the OPBCS seems to disappear, probably related to increasing agricultural intensification and commercialisation. I extensively studied the nature of the documents that reflected the new rules of land ownership and land access. The nature of the contracts did not allow a simple classification in customary versus legal contracts, but a large variety of hybrid forms. These hybrid forms span the continuum from written contracts with legal status, via so-called *petits papiers* (quasi-legal paper documents with variable backing by local-customary and national-legal authorities and hence various forms of conflict resolution in case of disagreement) to oral contracts, as these

latter contracts did not disappear after the titling intervention as the moral force of oral agreements is still sufficiently high. I interpret changing contract forms along three dimensions: changes from oral to written agreements, from written agreements without witnesses to agreements that are witnessed on both sides, and by contracts that are backed up by customary authorities such as local chiefs to contracts backed up by the formal-legal state authorities. I interpret the latter change as evidence of changes in institutional power, as different contracts derive their legitimacy from different authorities but at the same time contribute to the legitimacy of those authorities. In that chapter I use the concept of *bricolage* (the skilful use of a hybridity of institutions by both parties) as a means of understanding why there is no simple institutional evolution as proposed by the evolutionary theory of land rights.

Soil fertility management

I also investigated soil fertility practices in the OPBCS and in newer forms of agriculture. In Chapter 4 I empirically investigated claims about the importance of long fallows (arguably essential because of long-term cropping practices that negatively impact on soil fertility, Chapter 2) by comparing oil palm fallows of different duration and agricultural fields with and without young oil palms for biological, chemical and physical soil quality. My results confirmed earlier claims by Koudokpon *et al*. (1994) that chemical soil fertility did not increase with fallow duration. I was also unable to demonstrate enhanced biological soil quality (assessed through activity of earthworms and arbuscular mycorrhizal fungi) after longer-duration fallows. My data did show increases in physical soil quality (which translate into workability) with fallow length, providing experimental support for an earlier suggestion by Koudokpon *et al*. (1994). I propose that the lack of effects of fallow duration may be related to the current management of agricultural fields (use of mineral fertiliser and organic amendments), which prevented those fields from soil fertility decline. From that perspective it is important to investigate how further agricultural intensification towards permanent land use can be supported by judicious use of mineral fertilisers and organic amendments, taking the nature of the contracts for land access into account. The study also provided confirmation that fallow length is not primarily a response to soil fertility degradation but an expression of control over land.

Use of household waste on the Adja plateau seems to be increasing. Increased security of land access (in relation to the changes caused by the land titling programme) may also increase willingness to invest in land through organic amendments (household waste) and mineral fertiliser and to allow a shift towards more permanent land use that is more compatible with agricultural intensification and commercialisation. In Chapter 5 I tested, together with eight farmers, effects of organic amendments, in combination with mineral fertiliser, on biomass yield of maize. In the absence of fertiliser or household waste maize

grain yield was low, around 700 kg ha^{-1}. Both fertiliser and household waste increased yield, but the effect of household waste (increases of 800-1500 kg ha^{-1}) was much larger than that of mineral fertiliser (increases of 300-500 kg ha^{-1}). The lack of a significant statistical interaction between both sources of amendments indicated that household waste did not affect fertiliser use efficiency. The experiment, admittedly of short duration, did not lead to increased organic matter contents. The nature (decomposability) of the household waste as organic amendment was not assessed.

7.3 The socio-technical interfaces of soil fertility management

The notion of socio-technical interfaces treats human and non-human actors symmetrically and suggests that agricultural intensification is shaped by technical and social drivers (Abdullaev and Mollinga, 2010).

First of all it is important here to recall that soil quality (soil fertility) is plural, including chemical, physical and biological aspects. Local assessments of soil quality often include all aspects: colour (a proxy for amount of soil organic matter, i.e. chemical soil quality), workability (a proxy for bulk density, i.e. physical soil quality), and earthworm casts (biological soil quality). Farmers also use leaf colour (a proxy for leaf nutrient content) and crop productivity as integrated parameters for soil fertility. Our interdisciplinary methodological approach maps out how social sciences (land tenure with landowners and tenants) and biophysical sciences (land management practices) meet to analyse the making of soil quality. My findings indicate that soil quality (chemical, physical and biological) should be viewed as emergent from the socio-technical interface of land management practices and land tenure. Several conditions, such as multiple land tenure contexts (formal and customary) and power relations over the land shape those socio-technical interfaces as part of the political ecology of soil fertility/quality. Therefore, understanding the connection between land tenure and soil fertility (the socio-technical interfaces) is key to theory, practice and policy of land titling and soil fertility management. This is likely since the impact of land titling in my study went beyond just changing land tenure, but led indirectly to biophysical changes in soil quality.

The socio-technical interface of oil palm fallowing served more a political purpose than an ecological one. (The long duration of oil palm fallow resulted only in a small improvement in physical soil quality.) Consequently, I draw attention to the dual social and agronomic roles of long-term fallowing in the OPBCS. My analysis points towards an explanation for long-duration oil palm fallows through landowners' interests in maintaining control over land (Chapter 2). Moreover, I observed a decline in the intercropping with oil palm in villages where the land titling intervention was implemented. My observation is also consistent with my conclusion that the OPBCS is more a strategy for the assertion of rights than a soil fertility management measure *per se*. The oil palm fallow was used as a visible

sign of claims of land ownership, even though the long duration of the fallow put restrictions for tenants to grow food crops and hence negatively influenced a further agricultural intensification. It is therefore important to realise that the changing government policy of Benin, whereby oil palm got assigned a strategic role and where areas that are not very suitable from an agro-ecology point of view for commercial palm oil production, will be designated for plantations, may have both national but also unexpected local consequences (see below).

A further socio-technical interface relates to the use of household waste as organic amendments to increase crop productivity and to enhance soil fertility. Interest for household waste exists among both landowners and tenants. However, the use of the household waste requires that tenants can utilise land with some degree of security if long-term benefits for crop productivity are the objective (Chapter 5). This degree of security finds expression in the nature of (paper-based) contracts for tenants. It may therefore not be coincidental that in the MCA villages more fields were rented out to tenants, the group that somewhat more often used household waste than landowners (Chapter 3). Where long-term security is not provided to tenants, the nature of organic waste used (high-N materials such as animal (goat) manure versus low-N materials such as stover or oil palms fronds) could be affected. As another important aspect of political ecology of soil fertility, I hypothesise that the new paper-based contract for tenants together with the use of household waste generates a dynamic socio-technical interface which will have implication for soil quality.

These different socio-technical interfaces indicate that social and technical dimensions of soil quality are connected at multiple-levels to enable agricultural intensification in the OPBCS.

The rise of commercial oil palm (for palm oil) would create new socio-technical interfaces. New plantations could allow entrance of new actors on the Adja plateau (absentee urban elites as new tenants who compete with the landowners) and new tenure rules for landowners and (new) tenants, create new scarcity of land for food cropping (through land immobilisation) and hence slowing down forms of agricultural intensification, and contribute to shifting power balances between representatives of customary and formal regimes. Whereas large-scale structural transformations in agricultural intensification in SSA often advocate state-driven technological intervention, they frequently seem to disregard enabling (local) institutional environments. My thesis demonstrates the need to tackle both the technical and (multi-level) institutional issues for oil palm intensification on the Adja plateau, with special attention for the existing institutional patchwork and the fact that the local actors behave as skilful *bricoleurs*. My study suggests an analysis of combined and interacting state-driven and local institutions of land use as an important knowledge gap in order to achieve agricultural intensification. Looking in retrospect, it seems that such local issues related to the

country's move towards more commercial palm oil production, were underestimated by the programme CoS-SIS.

7.4 The role of multiple institutions in tenure and soil fertility management

Cleaver (2002) coined the term institutional *bricolage* (often translated as patchwork, even though that insufficiently expresses the skills of the *bricoleur*), referring to people's development of skilful and flexible strategies in the face of multiple institutions. This description implies that institutional patchworks likely evolve in unpredictable ways rather than that institutions of the same domain evolve in a predictable linear fashion, whereby less 'fit' institutions are replaced by 'superior' institutions. Whereas North (1991) contended that institutions should reduce uncertainty and ambiguity in human interaction, ambiguity is a central characteristic of institutional *bricolage* and legal pluralism (Benda-Beckmann von, 2002). The *bricolage* model is an alternative to the blueprint linear model of institutional change. Clearly Cleaver and North occupy different positions on the role that ambiguity could play in shaping institutions and institutional change.

The MCA-initiative on the Adja plateau (Chapter 3) was not based on a deliberate wish to create a hybrid system. It started with the commonly held (but empirically poorly supported) evolutionary theory of land rights. That approach assumes and necessitates a simple replacement of customary by formal systems, because of superior 'fitness' (in the evolutionary sense) of systems based in formal law. In fact the theory assumes that formal law reduces ambiguity and dispute and therefore increases options for productive investment in land. In practice, I observed that both landowners and tenants did perceive ambiguities of both the existing (rather customary) system and the proposed changes therein (towards a rather formal system) as opportunities to manoeuvre at various social and legal levels, each to their own advantage. Different authorities (village chiefs, state representatives) also used ambiguities to maintain or even enlarge their sphere of influence. From my comparison between the different villages I concluded that formal and informal institutional systems could co-exist peacefully. In fact, a simplistic attempt to replace the customary system by a legal system of landownership created tensions, as claims to landownership were accompanied by evictions of tenants from land. The secondary modification of land access rules did then result in conflict reduction, recognizing the disadvantages of that simplistic theory.

What emerged (or what was 'caused' by MCA on the Adja plateau) is a hybrid system that combines informal and formal elements. A law instituted about 100 years ago was replaced in 2007 by a new land law. The land titling initiated under this new land law initiated written paper contracts to regulate short-term tenure arrangements. It is important to demarcate this written paper contract for temporary arrangement from *petits papiers* (Delville, 2002), which is a quasi-legal document for recording purchased land transactions in francophone rural Africa. Entrepreneurial elite tenants can take advantage of the legally

strengthened paper contract, for instance based on the fact that the paper contracts make no mention of the transferability of rights to third parties. This implies that new tenants could enter into arrangements with third parties in a legal vacuum that presents a context for ambiguity that can become a threat for tenants. I suggest that the content of the contracts (for temporary arrangements) should be further clarified with specification of the rights of different parties. However, any formal system of clarification that ends in terminating local land tenure practices would almost certainly be a recipe for conflict.

Bricolage in case of land tenure is not just a response to the attempt to introduce new formal land tenure laws and regulations. *Bricolage* is also a tool of customary land management as has been shown in other studies of land tenure in Africa (Adjei-Nsiah *et al.*, 2008), as under such conditions skilful use of ambiguities in rules can be equally beneficial. Crafting control over land by creating flexibility around various types of arrangement seems characteristic of customary land tenure systems. Such uses of ambiguity seem prerequisite for processes of institutional change (Ostrom and Basurto, 2011). But *bricolage* also implies the need for an adequate and explicit understanding of how power relations govern actions and outcomes. Power relations (and competing claims for power, as in the case of assessing which local and state authorities can sign the various documents) on the Adja plateau need further attention which the new contracts are implemented. Its study should start soon.

7.5 Power relations and their influence in soil fertility management

I applied theoretical insights from political ecology in order to examine connections between soil quality, landowners and tenants' land management practices and changes in institutions that regulate ownership and access to land. Political ecology has been chosen as the framework for critically analysing the interactions between social, technical and ecological processes around land issues, with particular attention to power relations (Steinberg, 1998, Andersson *et al.*, 2011).

Power is a 'fluid medium' that is produced collectively through social movements and networks of individuals seeking to achieve social, economic, environmental, and/or political goals (Allen, 2003). This broader definition of power is relevant to my study because it allows me to connect networks of power by landowners and tenants to the multi-level socio-technical interfaces. In my study, I observed manifestations of power at two levels in the OPBCS: (1) Oil palm fallow (duration) as a long-term assertion of power over land, (2) Changing authority over land (customary and formal tenure and hybrid contract forms).

With regard to the first manifestation I also observed the beginnings of changes in power relations. The land titling intervention resulted in conflict reduction of land access and land contracts for longer duration. As a consequence the importance of oil palm in the cropping system (and of oil palm fallow declined). This process added to an underlying trend of more permanent cropping with lower shares of oil palm. Consequently, new cropping

practices and new land arrangements changed the power relation inherent in this first manifestation. At the same time it likely enhanced forms of competition for power in the second manifestation, as detailed in chapter 3. Institutional reconfiguration brought in by the land titling programme redistributed bundles of power to different actors (landowners, tenants). The redistributed power (via paper-based contracts) materialised into changes at the socio-technical interfaces in relation to landowners and tenants. Paper-based contracts express social power that re-shapes the authority over land. Following the institutional reorganisation by the MCA, power over land rights and conflicts have been shifted to the legally recognized state structures of the SVGF, SCGFA and CoGEF (Chapter 3). Village chiefs are being replaced by CoGEF as the connection between state and local communities. This represents the beginning of a switch from the customary institution of chiefdom, which is primarily accountable to the residents of a village, to a state institution, which is accountable to the national government. These new institutional arrangements for regulating access to and use of land provide an emergent opportunity for the commercialisation of farming.

7.6 Suggestions to improve soil quality and strengthen agricultural intensification

Improving soil quality / fertility and strengthening agricultural intensification requires complementarity and trust between policy, practice and research. To realise this trust, researchers need to get involved as actor and help to bridge the gap between policy and the realities of farmer socio-technical practices. A crucial step is to recognise the internal and external limitations that often undermine the integrated development of research in general and hence also my study.

Limitations to my research

Two types of limitations could be identified to my present work. The internal limitation included a methodological choice in terms of diachronic versus synchronic studies. I decided to use a synchronic approach, capitalising on a natural experiment (the MCA intervention). I analysed villages and fields that were impacted or not by the intervention, investigating the nature of differences in practices between both villages. I also made use of a diachronic approach, using the earlier study on soil fertility on the Adja plateau by Brouwers (1993). However, I considered it difficult to extrapolate from that study. It seemed that Brouwers (1993), followed by Koudokpon *et al*. (1994), considered the OPBCS primarily as an innovative agroforestry system that would allow sustainable agriculture, despite high population pressure. My study casted doubt on the exclusive emphasis on the technical site of the OPBCS and indicated that several elements of the system (both the duration of the cropping phase and the duration of the subsequent fallowing phase) should be better interpreted as manifestations of competing claims over land. The sustainability of the system would then also be affected by changes in that power balance. So while the diachronic

approach was not immediately useful for my project, I also recognise limitations in the synchronic approach, as comparability between the villages suggested that the MCA villages were subject to more (or better documented) cases of land tenure conflicts (Table 3.2). A further (inevitable) limitation of my study was that the new documents for rental agreements had not yet become fully operational. While many people knew they are forthcoming and already seem to act on it, it is important that the official introduction of these new contracts be accompanied with studies on their effects. Such a study should capture the institutional dynamics emerging from the competition over authority between the customary and the formal system.

A more important limitation likely was the external context of the CoS-SIS programme that constrained my research focus while simultaneously offering new niches for socio-technical research in a different context. About the constraints, a meta-structure was adopted in the programme and this structure provides space to manoeuvre for research associates. Under the CoS-SIS programme philosophy the research associates were supposed to work (experiment) at institutional levels above the farm, next to the technical development at farm and local level for which the PhD carries responsibility. The programme made a choice for a crop (oil palm on Adja) that was not fortunate in all respects. The national policy with regard to oil palm (increased palm oil production for domestic and possibly export markets) did not automatically fit with the livelihood ambitions of the people living on the Adja plateau. For landowners, who were the only ones that could grow oil palm, palm oil was far less important than *sodabi*; and the long duration of palm fallowing served socio-political purposes more than soil fertility purposes. It is not evident that long-term land immobilisation, due to commercial oil palm plantations, will benefit them rather than a new class of commercial tenants (likely urban elites). For the original tenants, who could not grow oil palm and who saw oil palm achieving a height where it could out-shadow food crops as disadvantageous for their livelihood ambitions, increased emphasis on oil palm plantations would potentially reduce land available for food crops, negative affecting their attempts to intensify agriculture and to switch to commercial agriculture with products that fetch higher prices. So alignment of local livelihood ambitions and national priorities was assumed without much critical reflection, possibly strengthened by the idea that farmers constraints were above the farm level (and hence that institutional reforms at state level would result in opportunities for alleviating these farmer constraints). This assumption generated problems, and these were also encountered by the land titling intervention, when the formalisation of land property reduced tensions between landowners but increased tensions with tenants. By doing so, the programme neglected the inclusive participatory dialogue with local actors about their opportunities. Hence these pre-analytical choices made a fit of my research project with the programmatic ambitions difficult, because the CoS-SIS vision and the livelihood ambitions of landowners and tenants in my project diverged.

Policy and practice

The role of agricultural research is often overlooked as an aspect of the political ecology of intensification (Crane, 2009). Responding to pressure from national governments, research projects in African universities increasingly adapt their objectives to achieve a quick fit with state policies. However, because state policies do not often take into account farmers' issues, perspectives and practices, there is a risk that research increasingly alienates itself from these farmers as well. The mismatch between state policy and rural realities reflects on the quality of agricultural research. My study also suggests misalignment between policy and practice in the OPBCS (Table 6.1).

Table 6.1: Policy and practice overview

	Oil palm fallow	**Use of household waste as organic fertiliser**	**Land ownership**	**Land access regulations**
What is the government's view?	Undesirable (land law 2007)	Not relevant	Desirable	Desirable
What does the government try to do?	Promote intensification of improved oil palm	Research and promote only chemical fertiliser	Impose formal tenure laws	Ignore customary access rights
What is the practice on the ground?	Oil palm fallow is declining. Intercropping with young oil palm is disappearing	Increasing use of chemical fertiliser and use of organic amendments	Land title is in landowners' hands	Short-term paper contracts increasingly common
What the literature says	Is a response to soil fertility decline (Koudokpon *et al*., 1994)	The combination of mineral and organic fertilisers improves soil fertility and crop yields (Chivenge *et al.*, 2009, Chivenge *et al.*, 2011b)	Unclear about conflict resolution	Improves agricultural yield, sustainable land use and social equity (Yami *et al.*, 2011)

Differences between government policy and local practices on the ground are obvious from Table 6.1 for the use of household waste or organic amendments. State policy (and agricultural research) overlooks the use of organic amendments, whereas these are highly demand by the farmers in my area (in combination with mineral fertilisers for the more commercial crops). A similar mismatch is likely for oil palm plantations or oil palm fallows (sites where mature oil palm trees prevent the simultaneous production of food crops), where government policy to establish plantations will reduce the land available for food cropping on

Adja, but where current practices indicate intensification towards permanent cropping of annual food crops at the expense of oil palm. In Chapter 2, I provided a diagnosis of the constraints that farmers expressed. These constraints are different from the constraints diagnosed by the state (of which lack of sufficient locally produced palm oil is one).

Table 6.1 therefore also provides indications for the need to bridge between policy, university and farms on Adja plateau. In Benin, the reform process forced by structural adjustment of the economy led to a re-formulation of the extension services at local and regional level, which could potentially increase bureaucratic activities. Nevertheless, the challenge of bridging between policy, university and farms goes beyond calling scientists to work with farmers in a participatory manner, but developing new academic curricula and extension practices.

Based on the findings of my thesis, I recommend that extension services increasingly base their work on farmers' diagnoses of problems and aspirations, while still recognizing that there are often institutional issues that cannot be solved at farmers' level nor easily addressed by extension agents (Hounkonnou *et al.*, 2012); such as land tenure issues.

The need for training new types of researchers who are able to combine social science and natural science is compelling. My thesis indicates that such hybrid researchers, educated through a new curriculum, would be better adapted to African farming conditions. The new curriculum should contain theoretical as well as empirical perspectives from an interdisciplinary vision. Advocacy of this point does not, of course, detract from the need for (African) scientists to also generate fundamental scientific knowledge. However, we are aware that having both may be too much for the low budget of African universities. Therefore, a debate about the balance of both interests (scientific depth and width) would be an urgent challenge for the future of African agricultural universities. With regard to soil fertility, I strongly believe that African universities need to aim biophysical specialists capable to develop interdisciplinary research programmes combining the social and biophysical. My thesis can be seen as recognition that soil fertility and agricultural production inherently combine the social (research questions b, c, and d) with the natural (research questions a and d).

Research

On the Adja plateau, there are some gaps in knowledge on soil quality. Many sites had relatively low amounts of organic carbon (Chapters 4 and 5). Such low amounts may partly be attributable to the prevailing soil texture (sandy soils), but also fit in the discourse of declining soil fertility and loss of soil organic matter. Data from comparable sites that were collected at earlier times suggest that soil organic matter contents were also low at that time. However, only long-term trials can demonstrate the nature of changes in soil organic matter contents (if any) and the possibilities to increase these amounts with a simultaneous sustainable yield

increase. Because soil quality / fertility is not only chemical, such long-term investigations should not only include soil chemical assessments (organic carbon, nitrogen, phosphorus, potassium), but also soil physical properties (bulk density, porosity, water-holding capacity) and biological indicators of soil quality (arbuscular mycorrhizal fungi, earthworms). Recovery of soil biota through long-term fallowing and maintenance of soil biological diversity with sustainable intensification of agriculture needs to be tested in these long-term trials. Methods should both include state-of-the-art molecular methods (for micro-organisms) but also simple field techniques that would allow bridging the knowledge of soil ecologists with farmers' knowledge and know-how. Long-term carbon and nutrient models need to be applied to predict soil organic matter contents so that allocation of household waste can be matched with crop demands. I would for the future like to address questions such as: how is soil quality and how are crop yields affected in the long term by the use of household waste (Gentile *et al*., 2011) and combined fertiliser and organic resources (Ouedraogo *et al*., 2006)? How is soil organic matter (quantity and quality) affected by differential quality (Carbon: Nitrogen ratio) of the various forms of waste (Chivenge *et al*., 2011a)? How does that variable quality of household waste affect fertiliser use efficiency (Vanlauwe *et al*., 2011)? Differentiating sources of waste (and possibly removing toxic compounds that may now be included in household waste such as plastic or batteries) is also important.

Further challenging issues on socio-technical interfaces are the link between the recycling of household waste and land tenure formalisation to allow sustainable intensification; and a study of the long-term impact of the new paper contracts after their official implementation. We still incompletely know the extent to which the practice of combining mineral fertiliser and waste-derived organic amendments contributes to changes in tenurial arrangements. A follow-up study should use both the tenure status and the application of the household waste as independent variables, and test the contribution of both towards agricultural intensification.

Finally, my thesis also suggests the risk that new (and richer) tenants engage in temporary (but still longer-term) land contracts through the new paper contracts. The ability to enter into and hold legally-enforceable contracts that reinforce the tenants' rights to rent land, for up to 25 years, can be used by absentee tenants, i.e. persons resident outside the area, including urban elites engaged in land speculation, and potentially also by corporate interests. This new category of tenants would create new barriers to land access by poorer tenants. Under that scenario, long-term contracts could drive land immobilisation, and increase the numbers of landless tenants on the Adja Plateau. The risk for such an undesirable outcome is reinforced by national policy, which has designated oil palm as a priority crop (even on Adja) and encouraged private entrepreneurs to invest in the acquisition of large tracts of land for oil palm development. It would be important to investigate the behaviour of new (elite) tenants at

the beginning, the middle and towards the end of the rental period with respect to the management of the land.

7. References

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8. Summary

This thesis explores socio-technical and institutional dimensions of agricultural intensification in the oil palm-based cropping system on the Adja plateau, Benin. The oil palm-based cropping system has been described as an agroforestry system with a stage of small oil palms underneath which food crops are grown by tenants and a fallow stage with dense stands of mature oil palms. In this system, landowners grow oil palms mainly for the artisanal production of palm wine and its distilate *sodabi*, rather than for palm oil, for which the region is unsuitable for climatological reasons. The system is apparently declining as a consequence of agricultural intensification and commercialisation. My thesis also explores the sustainability of this intensification. A starting point for this study was that agricultural intensification is not only technical and ecological, but also institutional. Both customary and formal land tenure institutions shape access to land on the plateau. Competition between and evolution of these multiple institutions also have ecological implications. The regression of the oil palm-based cropping system and the increasing use of mineral fertilisers are due to this evolving institutional arena. Agricultural intensification and commercialisation cause ecological changes. These changes have been analysed from a political ecology perspective with special attention for the role of power (the relation between landowners and tenants, and the ways in which they try to exercise control over land and land management practices) in soil fertility management.

Chapter 1 outlines the problem, the theories that inspired the research questions, and the research methodologies used in this thesis. I used technography as research methodology to understand soil fertility management in the oil palm- based cropping system. Political ecology was also a major source of inspiration. I focus on different actors' perspectives: landowners and tenants. The chapter reviews approaches in the study of the relationship between tenure security and land tenure institutions on the one hand, and investment in soil fertility on the other. The best known and most influential of these approaches (in academic and policy circles) suggests that customary land tenure maintains tenure insecurity and therefore hampers investments in soil fertility. My research focuses on four research questions:

(1) What are the constraints and opportunities for landowners and tenants with regard to soil fertility management practices in the oil palm-based cropping system on the Adja plateau? (2) How does land titling affect conflict (and conflict resolution) among landowners who claim ownership of the same plot? (3) How does land titling affect conflict (and conflict resolution) among landowners and tenants with regard to access to land for cropping purposes? The combination of changes in ownership and land access for tenants led to the next research question: (4) How does land titling and land access regulation affect soil fertility management practices by landowners and tenants?

Chapter 2 diagnoses the problem of land management on the Adja plateau in terms of competing claims between landowners and tenants. These claims evolve in conflicts over

practices that either reduce or improve soil fertility. Landowners use an extended oil palm fallow (more than ten years) with mature palms to restore soil fertility. Long fallows also contribute to maintaining their claim of ownership of the land. The land is leased to tenants to cultivate annual crops, grown intermixed with small (less than 2m high) oil palms. Competition between tenants and landowners is due to the fact that tenants severely prune the palms in an attempt to extend the cropping period, because their right to grow annuals terminates when these are shaded out by the palms. The long fallow is then stated by landowners as a necessary step to restore soil fertility after extended periods of cropping. Furthermore, I show that the oil palm-based cropping system on the Adja plateau is characterised by overlapping formal and customary institutions, and these overlapping and competing institutions have implications for the competing claims over cropping practices. Landowners and tenants try to use *bricolage* in order to derive benefit from institutional overlap and hence ambiguity. In an attempt to remedy the competing claims and practices, which make the oil palm-based cropping system both an agroforestry system and an arena for political struggle, land titling programmes have been implemented in some villages on the Adja plateau in 1995 and again between 2007 and 2012. I studied impacts of these titling programmes.

Chapter 3 extends the diagnostic study and provides a stronger institutional focus of land tenure. It demonstrates the implication of the multiple institutions on land access and ownership, and therefore on competing claims between landowners and tenants. I describe how the land titling intervention created a natural experiment where villages with and without the titling intervention could be compared. My data show that the land titling initially created land insecurity for tenants, as they were thrown off the land by owners who wanted to establish and demonstrate claims of ownership in an unambiguous way. Subsequently, arrangements were also made for new rules related to land access by tenants. Both arrangements (ownership and access by tenants) relied on a different mix of formal and informal practices, as evidenced by formal contracts and *petits papiers*. These different documents therefore express also competing claims over authority to deal with issues of land ownership and access. A comparison between villages with and without titling showed how titling enhanced on-going processes of intensification and commercialisation, as evidenced by increased use of mineral fertiliser. However, the changes on the Adja plateau cannot be causally attributed to the land titling programme, as both villages showed the same pattern of reduction of the oil-palm based cropping system. My study also indicated potential risks for new struggles over land if long-term contracts become available for new categories of tenants (including members of urban elites) as such contracts could lead to land immobilisation and land speculation, both of which have the potential to maintain land scarcity.

Chapter 4 addresses the empirical question about the positive impact of long-term oil palm fallows. It tests the question whether long fallows are needed for restoring soil fertility

(as landowners claim) or are an expression of the control over land (as tenants claim). My data show that increasing fallow length did not have any positive effect on biological and chemical soil quality, and on crop productivity, but that physical soil quality (and hence workability of the land) improved. It also showed that fallows, independent of duration, were not more fertile than agricultural land with and without immature palms. I ascribe lack of effects of soil fertility enhancement due to fallowing to the use of mineral fertiliser and organic amendments as part of the agricultural intensification and commercialisation on the plateau.

In Chapter 5, I describe a participatory experiment with eight farmers on the effects of mineral fertiliser and organic amendments on maize productivity. Organic amendments used are household waste, a mix of organic products that is increasingly being used by tenants because of its high-quality organic matter. My study shows that application of household waste and mineral fertiliser did not impact soil organic matter levels (related to its high decomposability). However, organic amendments had a much more beneficial effect on increasing maize yield than mineral fertiliser. There was no interaction between organic amendments and mineral fertiliser, indicating that household waste did not improve agronomic use efficiency of mineral fertiliser. The study also shows how tenure contracts (share cropping) will impact on the evaluation of both practices. As application of mineral fertiliser shifts the terms of division of the yield (the landowner received half of the yield rather than one third if fertiliser is provided), application of mineral fertiliser may not be very beneficial for tenants, whereas the application of household waste (which is taken from the tenants' households) does not shift the term of the agreement and is therefore much more favourable. However, both local cultural values of cleanliness and amounts available constrain the use of household waste and thus its impact on cropping systems.

The discussion in Chapter 6 cuts across and integrates three issues: (1) the implication of long-term fallowing in the social reality of the oil palm-based cropping system; (2) the role of institutional plurality and associated power relationships in soil fertility management; (3) on-going processes of agricultural intensification and commercialisation. My study suggests that formal and customary land tenure institutional systems can be blended to generate a hybrid system (viz. the new land access regulation in Chapter 3). In such a hybrid system, local authorities compete over the nature of contracts and the authority to settle disputes. In such a hybrid system, both landowners and tenants lose and gain some of their powers. Both parties will therefore continue to resort to *bricolage* strategically. Such a hybrid system might contribute to sustainable soil fertility management. Further research questions should highlight how this new land access regulation for tenants and the use of household waste (as part of the intensification) have socials impact on the Adja plateau.

Samenvatting

In dit proefschrift onderzoek ik de socio-technische en institutionele dimensies van intensivering van de landbouw in een op oliepalm gebaseerd teeltsysteem (OPBCS genoemd) op het Adjaplateau in Benin. Dit OPBCS is eerder beschreven als een vorm van agroforestry, met een stadium van lage oliepalmen waaronder voedselgewassen geteeld worden door pachters; en een stadium van braak waar de oliepalmen uitgroeien tot een gesloten vegetatie van rijpe oliepalmen. In dit systeem gebruiken de landeigenaren de oliepalm hoofdzakelijk voor de kleinschalige productie van palmwijn en de vandaar afgeleide alcoholische drank *sodabi* (een soort palmjenever), en niet of nauwelijks voor palmolie, doordat het gebied vanwege de klimatologische omstandigheden maar weinig geschikt is voor palmolieproductie. Het OPBCS is thans zeldzaam aan het worden en dat wordt waarschijnlijk veroorzaakt door toenemende commercialisering en intensivering van de landbouw. In mijn proefschrift onderzoek ik daarom ook de duurzaamheid van deze intensivering. Uitgangspunt voor mijn studie was dat landbouwintensivering niet alleen als technisch en ecologisch proces moet worden beschouwd, maar ook een institutionele dimensie heeft. Zowel lokaal-informele als op formeel recht gebaseerde instituties met betrekking tot eigendom en pacht bepalen de toegang tot land op het plateau. Concurrentie tussen en geleidelijke veranderingen in deze verschillende instituties hebben op hun beurt weer ecologische gevolgen. De teruggang van het OPBCS en het toenemende gebruik van kunstmest zijn mede het gevolg van deze veranderende institutionele arena. Intensivering en commercialisering van de landbouw veroorzaken ecologische veranderingen. Deze veranderingen worden in mijn proefschrift geanalyseerd vanuit het perspectief van de politieke ecologie, met speciale aandacht voor de rol van macht (relaties tussen landeigenaren en pachters; en de manieren waarop beide partijen proberen de controle over land en landgebruiksvormen te behouden) bij het beheer van bodemvruchtbaarheid.

In hoofdstuk 1 schets ik het probleem, de theorieën die de basis vormen voor het formuleren van de onderzoeksvragen, en de in dit proefschrift gebruikte onderzoeksmethodes. Ik gebruik technographie als een onderzoeksmethodologie om bodemvruchtbaarheidsbeheer in het OPBCS te begrijpen. Politieke ecologie vormt eveneens een belangrijke bron van inspiratie. Ik richt me voornamelijk op de verschillende perspectieven van landeigenaren en pachters. Het inleidende hoofdstuk geeft een overzicht van de benaderingen in de studie naar verbanden tussen enerzijds landzekerheid en instituties die van invloed zijn op landrechten, en anderzijds investeringen in het handhaven en verbeteren van de bodemvruchtbaarheid. De best bekende en meest invloedrijke benadering (zowel in termen van onderzoeksinstituten en universiteiten, en ook bij beleidsmakers) is dat landrechten gebaseerd op informeel recht onzekerheid van landrechten in stand houden en

daardoor remmend werken op investeringen in bodemvruchtbaarheid. Mijn onderzoek richtte zich op de volgende vier onderzoeksvragen:

(1) Wat zijn de beperkingen en mogelijkheden voor landeigenaren en pachters met betrekking tot bodemvruchtbaarheidsbeheer in het OPBCS op het Adjaplateau? (2) hoe beïnvloedt een programma dat landeigendom zeker wil stellen het ontstaan en ook weer oplossen van conflicten tussen eigenaren die beiden eigendom van een veld opeisen? (3) hoe beïnvloedt een programma voor vaststelling van landeigendom het ontstaan en de oplossing van conflicten tussen landeigenaren en pachters met betrekking tot de toegang tot land voor de teelt van voedselgewassen? De combinatie van veranderingen in eigendomsrechten en toegangsregels voor pachters leidde tot de vierde onderzoeksvraag (4) op welke wijze beïnvloeden zulke programma's voor vaststelling van eigendom en voor vaststellen van toegang tot land bodemvruchtbaarheidsbeheer door landeigenaren en pachters?

In hoofdstuk 2 wordt een diagnose gegeven van het probleem van bodemvruchtbaarheidsbeheer op het Adjaplateau. De nadruk ligt daarbij op de tegengestelde aanspraken op land en landgebruik door landeigenaren en pachters. Deze aanspraken hangen samen met vormen van landbouw en bodembeheer die de bodemvruchtbaarheid doen afnemen of juist verbeteren. Landeigenaren geven de voorkeur aan een lange periode van braak (meer dan tien jaar) met volwassen oliepalmen zodat de bodemvruchtbaarheid langs natuurlijke weg hersteld kan worden. Een lange duur van braak (met daarop oliepalm) draagt ook bij tot het handhaven van hun aanspraken op eigendom van het veld. Het land wordt verpacht aan pachters die éénjarige voedselgewassen telen, waartussen lage oliepalmen (lager dan 2 meter) groeien. De concurrentie tussen landeigenaren en pachters is het gevolg van het feit dat de pachters de oliepalmen intensief snoeien als deel van hun strategie om het land zo lang mogelijk toegankelijk te houden voor de teelt van landbouwgewassen, omdat hun recht om voedselgewassen te telen ophoudt wanneer de oliepalm hoger dan 2 meter is en daarmee de voedselgewassen beschaduwt. Landeigenaren stellen om die reden dat een lange braakperiode noodzakelijk is om de bodemvruchtbaarheid te herstellen na deze lange teeltperiode. In dit hoofdstuk laat ik daarnaast zien dat het OPBCS op het Adjaplateau gekarakteriseerd wordt door overlappende informeel-lokale instituties en formele instituties. Deze overlappende en concurrerende instituties op hun beurt hebben weer gevolgen voor de conflicterende aanspraken met betrekking tot landbouwpraktijken. Landeigenaren en pachters proberen hun toevlucht te nemen tot *bricolage* (het kundig gebruik maken van deze institutionele dubbelzinnigheid) om daardoor optimaal te profiteren van deze institutionele overlap en dubbelzinnigheid. In een poging om de concurrerende aanspraken op land en de concurrerende landgebruikspraktijken, ten gevolge waarvan het OPBCS zowel een agroforestry systeem is en een arena voor politieke strijd, te reguleren zijn er programma's voor landeigendomsrechten geïmplementeerd in verschillende dorpen op het plateau in 1995 en opnieuw tussen 2007 en 2012 Ik bestudeerde het effect van deze programma's voor vaststelling van eigendomsrechten.

Hoofdstuk 3 verdiept de diagnostische studie van hoofdstuk 2 en geeft een sterkere nadruk op de institutionele dimensie van landeigendoms- en landgebruiksregels. In dit hoofdstuk laat ik de implicaties zien van deze institutionele diversiteit met betrekking tot landeigendom en landtoegang, en daarmee op de concurrerende aanspraken tussen landeigenaren en pachters. Ik beschrijf hoe een programma voor vaststellen en formaliseren van eigendomsrechten als het ware een natuurlijk experiment is waardoor ik dorpen die deel uitmaakten van dat programma kon vergelijken met dorpen die daar geen deel van uitmaakten. Mijn gegevens laten zien dat dit programma aanvankelijk de zekerheid van toegang tot land voor pachters deed afnemen, doordat hun contracten beëindigd werden en ze van het land verjaagd werden door landeigenaren die hun eigendomsrechten op ondubbelzinnige wijze wilden bewijzen. In het vervolgtraject werden daarom nieuwe regels bedacht om de toegang tot land voor pachters zeker te stellen. Beide soorten regelingen (eigendomsrechten, toegangsrechten) maken gebruik van een mix van formele en informele regels, waarbij het relatieve belang van beide verschilt tussen beide soorten regelingen. Bewijzen hiervoor werden gevonden in formele contracten en zogenaamde *petits papiers*, documenten zonder wettige status die echter wel beschouwd worden als een formeel document. Deze verschillende typen van contracten weerspiegelen dan ook concurrentie om de autoriteit die gerechtigd is in te grijpen bij problemen over eigendoms- en toegangsrechten. Een vergelijking tussen dorpen met en zonder dit landtoewijzingsprogramma liet zien hoe in dorpen waar dit programma zich afspeelde dit proces bestaande processen van intensivering en commercialisering van de landbouw versnelde. Bewijs hiervoor werd gevonden in meer gebruik van kunstmest in de dorpen van het programma in vergelijking met dorpen zonder dit programma. Het is tegelijkertijd zo dat de veranderingen op het Adjaplateau niet volledig toegeschreven kunnen worden aan dit landtoewijzingsprogramma, omdat in beide typen dorpen er sprake was van sterke teruggang van het OPBCS. Mijn studie laat ook zien dat de nieuwe regels niet zonder risico zijn. Er kan namelijk daardoor nieuwe strijd over land ontstaan, vooral indien lange-termijncontracten beschikbaar komen voor nieuwe soorten pachters, waaronder mensen uit steden die op deze wijze ook aanmerking komen voor land. Daardoor kan uiteindelijk de beschikbare hoeveelheid landbouwgrond afnemen en kan grondspeculatie toenemen, leidend tot landschaarste en hoge prijzen voor pachtcontracten.

In hoofdstuk 4 onderzoek ik de vraag naar het positieve effect van een lange periode van braak in het OPBCS. Ik test de claim dat lange braak noodzakelijk is om bodemvruchtbaarheid te herstellen (zoals de landeigenaren beweren) of dat lange braak een uitdrukking is van controle over land door die eigenaren (zoals de pachters beweren). Mijn resultaten laten zien dan een langere periode van braak geen positieve effecten had op de biologische en chemische bodemkwaliteit, maar dat de fysische bodemkwaliteit (en daarmee de bewerkbaarheid van het land en de daarmee samenhangende arbeidsinspanning) verbeterde bij langere braak. Mijn resultaten lieten ook zien dat braakland niet vruchtbaarder was dan land dat al

tien jaar voor landbouw werd gebruikt, onafhankelijk van de vraag of op die akkers nog lage oliepalmen stonden of niet. Ik schrijf het gebrek aan effect van braak toe aan het gebruik van kunstmest en toevoegingen van organische stof (organisch afval van huishoudens), die op zijn beurt weer het gevolg is van de toegenomen commercialisering en intensivering van de landbouw.

In hoofdstuk 5 beschrijf ik een participatief experiment met acht boeren over het effect van kunstmest en compost op de productiviteit van mais. Deze compost bestaat uit organisch huishoudelijk afval, een product dat meer en meer populair is, vooral bij pachters, vanwege de hoge kwaliteit en stikstofleverend vermogen van de organische stof. Mijn studie toonde geen effecten aan van kunstmest en compost op de voorraad van organische stof; gegeven de hoge kwaliteit (afbreekbaarheid) van de compost was dit in overeenstemming met mijn verwachtingen. Maar toevoegen van compost had een veel sterker positief effect op de maïsproductie dan kunstmest. Er was geen interactie (synergie) tussen kunstmest en compost, wat er op wijst dat compost niet leidt tot een hogere efficiëntie waarmee de stikstof uit de kunstmest gebruikt wordt. Mijn studie laat eveneens zien hoe pachtcontracten (in het bijzonder *share cropping*, een contractvorm waarbij de opbrengst over beide partijen verdeeld wordt in een vooraf afgesproken verhouding) invloed hebben op de beoordeling van de wenselijkheid van zulke vormen van verbetering van de bodemvruchtbaarheid. Omdat kunstmest de verdeling van de opbrengst verandert (landeigenaren krijgen de helft van de opbrengst als ze de kunstmest leveren, maar slechts een derde als ze geen kunstmest ter beschikking stellen), is het gebruik van kunstmest niet van groot voordeel voor de pachters. Aan de andere kant is gebruik van compost (afkomstig van hun eigen huishouden, en waarbij de meeropbrengst alleen hun zelf ten goede komt) een veel aantrekkelijker optie. Tot slot moeten ook lokale culturele waarden (het belang van reinheid, dwz de afwezigheid van afval) en de vraag naar de beschikbaarheid van afval in ogenschouw worden genomen bij het beantwoorden van de vraag welke beperkingen bij het gebruik van dit afval optreden en wat daardoor hun betekenis is voor productiviteitsverhoging in de landbouw.

De discussie in hoofdstuk 6 integreert drie thema's: (1) de implicatie van de lange duur van braak in de alledaagse werkelijkheid van het OPBCS; (2) de rol van institutioneel pluralisme en de daarmee geassocieerde machtsverhoudingen in bodemvruchtbaarheidsbeheer; (3) thans optredende processen van intensivering en commercialisering van de landbouw. Mijn studie geeft aanwijzingen dat formele en lokaal-informele systemen van landeigendom en –toegang samen kunnen komen in een gemengd systeem (de nieuwe regels die in hoofdstuk 3 zijn beschreven). In zo'n hybride systeem zullen echter verschillende autoriteiten blijven concurreren over de specifieke aard van de contracten en het gezag waarmee ze eventuele conflicten kunnen beslechten. In zo'n hybride systeem zijn landeigenaren en pachters zowel winnaars als verliezers. Het valt daarom te verwachten dat beide partijen hun toevlucht blijven nemen tot *bricolage*, het strategisch gebruik van de

dubbelzinnigheden die uit zulke mengvormen voorkomen. Desondanks zal een dergelijk hybride systeem kunnen bijdragen tot meer duurzaam bodemvruchtbaarheidsbeheer. Verdere onderzoeksvragen dienen kennis te genereren hoe deze nieuwe regels voor landtoegang voor pachters en hoe het gebruik van huishoudelijk organisch afval sociale effecten op het Adjaplateau zullen hebben.

Résumé

Cette thèse explore les dimensions socio-techniques et institutionnelles de l'intensification agricole dans le système de culture à base de palmier à huile sur le plateau Adja au Bénin. Il a été décrit comme un système agro-forestier avec une étape de petits palmiers à huile en dessous de laquelle les vivriers sont cultivés par les tenanciers et une étape de jachère avec des pieds denses de palmiers à huile matures. Dans ce système, les propriétaires font pousser des palmiers à huile principalement pour la production artisanale de vin de palme et son distillat *sodabi*, plutôt que l'huile de palme, pour laquelle la région ne convient pas pour des raisons climatologiques. Apparemment, le système est en déclin comme conséquence de l'intensification agricole et la commercialisation. Ma thèse explore également la durabilité de cette intensification. Un point de départ de cette étude est que l'intensification agricole n'est pas seulement technique et écologique, mais aussi institutionnelle. Les institutions foncières coutumières et formelles façonnent l'accès à la terre sur le plateau. La concurrence mutuelle et l'évolution de ces multiples institutions ont également des implications écologiques. La régression du système de culture de palmier à l'huile et l'utilisation croissante d'engrais minéraux sont dues à cette arène institutionnelle en évolution. L'intensification agricole et la commercialisation sont aussi la cause de changements écologiques. Ces changements ont été analysés d'une perspective d'écologie politique avec une attention particulière pour le rôle des relations de pouvoir (entre propriétaires et tenanciers, et les moyens par lesquels ils tentent d'exercer un contrôle sur les terres et les pratiques de gestion des terres) dans la gestion de la fertilité des sols.

Le chapitre 1 décrit le problème, les théories qui ont inspiré les questions de recherche, et les méthodes de recherche utilisées dans cette thèse. J'ai utilisé *la technographie* comme méthodologie de recherche pour comprendre la gestion de la fertilité des sols dans les systèmes de culture à base de palme huile. L'écologie politique a également été une source d'inspiration majeure. Je me concentre sur les points de vue des différents acteurs: propriétaires fonciers et les tenanciers. Le chapitre passe en revue les approches dans l'étude de la relation entre sécurité fonciere et les institutions foncières d'une part, puis les investissements dans la fertilité des sols d'autre part. Le plus connu et le plus influent de ces approches (dans les milieux universitaires et de politiques agricoles) suggère que le régime foncier coutumier maintient l'insécurité foncière et donc entrave les investissements dans la fertilité des sols. Ma recherche porte sur quatre questions de recherche:

(1) Quelles sont les contraintes et les opportunités pour les propriétaires et les tenanciers en ce qui concerne les pratiques de gestion de la fertilité des sols dans les systèmes de culture à base de palme huile sur le Adja plateau? (2) Comment les titres fonciers affectent la résolution des conflits entre les propriétaires fonciers qui revendiquent la propriété de la même parcelle? (3) Comment les titres fonciers affectent les conflits (et leur résolution) chez

les propriétaires et les tenanciers en ce qui concerne les droits d'accès à la terre pour y cultiver? La combinaison des changements dans les droits de propriété et d'accès aux terres pour les tenanciers a conduit à la prochaine question de recherche: (4) Comment les titres de propriété foncière et la réglementation de l'accès des terres affectent la fertilité des sols et pratiques de gestion par les propriétaires et les tenanciers?

Le chapitre 2 diagnostique le problème de la gestion des terres sur le plateau Adja en termes de réclamations contestées entre propriétaires et tenanciers. Ces réclamations évoluent dans des conflits autours des pratiques de gestion qui dégradent ou améliorent la fertilité du sol. Les propriétaires utilisent une longue jachère (plus de dix ans) avec des palmiers matures pour restaurer la fertilité des sols. Les longues jachères contribuent également au maintien de la propriété de la terre. Les terres sont louées à des locataires pour des cultures annuelles, associées avec de petits palmiers à huile (moins de 2m de haut). Les réclamations contestées entre les tenanciers et les propriétaires fonciers sont dues au fait que les tenanciers taillent sévèrement les palmiers dans une tentative de prolonger la période de culture, parce que leur droit de culture se termine lorsque les vivriers sont ombragés par les palmiers. La longue jachère est alors déclarée par les propriétaires comme une étape nécessaire pour restaurer la fertilité du sol après de longues périodes de culture. En outre, le système de culture à base de palme à huile sur le plateau Adja est caractérisé par le chevauchement des institutions formelles et coutumières, et ces institutions ont des conséquences pour les réclamations contestées autours des pratiques culturales.

Les propriétaires et les tenanciers tentent d'utiliser le concept de *bricolage* afin de tirer profit de chevauchement institutionnel et donc de l'ambiguïté. Pour tenter de remédier à des réclamations et des pratiques contestées, qui rendent le système de culture avec palmiers à huile à la fois un système agro-forestier et une arène de lutte politique, des programmes d'enregistrement des terres ont été mises en œuvre dans certains villages du plateau Adja en 1995 et de nouveau entre 2007 et 2012. J'ai étudié les impacts d’un de ces récents programmes d'enregistrement.

Le chapitre 3 étend l'étude diagnostique et fournit une analyse institutionnelle plus poussée de la tenure foncière. Il démontre l'implication des institutions multiples sur l'accès aux terres et à la propriété, et donc sur les réclamations contestées entre propriétaires et tenanciers. J’y ai décris comment l’intervention d'attribution de titres fonciers a créé une expérimentation naturelle où les villages avec et sans intervention pourraient être comparés. Mes données montrent que la délivrance de titres fonciers, initialement, crée l'insécurité foncière pour les tenanciers, car ils ont été expulsés de la terre par les propriétaires qui voulaient établir et démontrer leur preuve de propriété d'une manière non équivoque. Par la suite, des dispositions ont été également prises pour de nouvelles réglementations relatives à l'accès aux terres par les tenanciers. Les deux types d’arrangements (propriété et accès par les tenanciers) comptent sur une combinaison différente des pratiques formelles et informelles,

comme en témoignent les contrats formels et *petits papiers*. Ces différents documents expriment donc aussi des réclamations contestées autour du pouvoir de traiter des questions de propriété foncière et d'accès. Une comparaison entre les villages avec et sans titres fonciers a montré comment l'intervention a amélioré les processus en cours d'intensification et de commercialisation, comme en témoigne l'utilisation accrue d'engrais minéraux. Cependant, les changements sur le plateau Adja ne peuvent pas être causalement attribués au programme de distribution de titres fonciers uniquement, puisque les deux villages (avec et sans) ont montré la même tendance de réduction du système de culture à base palmier à huile. Mon étude a également indiqué des risques potentiels pour de nouvelles luttes pour acquisition de terres si les contrats à long terme sont disponibles pour de nouvelles catégories de tenanciers (y compris les élites citoyens urbains) pour lesquelles ces contrats pourraient conduire à l'immobilisation et la spéculation foncière, qui tous deux ont le potentiel de maintenir la rareté des terres.

Le chapitre 4 traite de la question empirique de l'impact positif des longues jachères à palmiers à huile. Il teste si les longues jachères sont nécessaires dans la restauration de la fertilité des sols (comme le prétendent les propriétaires) ou plutôt sont l'expression du contrôle de la terre (comme le prétendent les tenanciers). Mes données montrent que l'augmentation de la longue jachère n'a eu aucun effet positif ni sur la diversité biologique ni sur la qualité chimique du sol ni sur sa productivité. Par contre la qualité physique (donc la facilité de travailler la terre) est améliorée. Mes travaux ont également montré que les jachères, indépendamment de la durée, n'étaient pas plus fertiles que les terres agricoles. J'attribue le manque d'effets positifs de la jachère sur l'amélioration de la fertilité des sols à l'utilisation d'engrais minéraux et amendements organiques dans le cadre de l'intensification de l'agriculture et de la commercialisation sur le plateau.

Dans le chapitre 5, je décris une expérience participative avec huit agriculteurs sur les effets des engrais minéraux et amendements organiques sur la productivité du maïs. Les amendements organiques utilisés sont des déchets ménagers, un mélange de produits organiques qui est de plus en plus utilisé par les tenanciers en raison de sa matière organique de haute qualité. Mon étude montre que l'application des ordures ménagères et des engrais minéraux n'a pas d'incidence sur les taux de matières organiques du sol (lié à leur forte décomposition). Toutefois, les amendements organiques ont un effet beaucoup plus bénéfique sur l'augmentation du rendement de maïs que l'engrais minéral. Il n'y avait aucune interaction entre les amendements organiques et les engrais minéraux, indiquant que les déchets ménagers n'ont pas amélioré l'efficacité de l'utilisation agronomique/d'engrais minéraux. L'étude montre également que les contrats d'accès (métayage) auront un impact sur l'évaluation de l'amendement organique et l'engrais minéral. En effet, puisque l'application des engrais minéraux déplace les termes de division du rendement (le propriétaire qui fourni l'engrais reçoit la moitié du rendement plutôt que le tiers), elle peut ne pas être très bénéfique

pour les metayeurs, alors que la demande des déchets ménagers (qui est tiré des ménages de tenanciers) ne change pas les termes du partage et est donc beaucoup plus favorable. Toutefois, les valeurs culturelles locales de propreté et la disponibilité des déchets ménagers limitent leur utilisation et donc impact sur les systèmes de culture.

La discussion dans le chapitre 6 transcende et intègre trois questions: (1) les interfaces socio-techniques de la gestion de la fertilité des sols, (2) le rôle de la pluralité des institutions et des relations de pouvoir associées à la gestion de la fertilité des sols; (3) le processus d'intensification agricole et de commercialisation en cours. Mon étude suggère que les systèmes institutionnels fonciers formels et coutumiers peuvent être combinés pour générer un système hybride (à savoir la nouvelle réglementation de l'accès aux terres dans le chapitre 3). Dans un tel système hybride, les autorités locales entrent en concurrence sur la nature des contrats et le pouvoir de régler les différends. Dans un tel système hybride, propriétaires et tenanciers perdent et gagnent une partie de leurs pouvoirs. Tous les deux parties continueront donc de recourir au *bricolage* stratégique. Un tel système hybride pourrait contribuer à la gestion durable de la fertilité des sols. D'autres questions de recherche devraient mettre en évidence comment cette nouvelle réglementation de l'accès aux terres pour les tenanciers et l'utilisation des déchets ménagers ont des impacts sociaux sur le plateau Adja.

What is CoS-SIS?

Definition and Purpose

Convergence of Sciences-Strengthening Innovation Systems is an action research programme in Benin, Ghana and Mali. It carries out scoping and diagnostic studies, agrarian system analyses and participatory field experiments with innovation platforms at the local, district and national levels. Its purpose is to identify pathways for creating opportunity for smallholder farmers in West Africa. Focusing on the enabling conditions at levels higher than the field and farm, the Programme supports sustainable intensification of smallholder farming for food security.

Partners and Funding

CoS-SIS is a partnership among the *Université d'Abomey-Calavi* at Cotonou, Benin; the *University of Ghana* at Legon, Ghana, and the *Instut Polytechnique Rural de Formation et Recherche Appliquée*, at Katibougou, Mali; and *Wageningen University*, and the *Royal Tropical Institute* in the Netherlands. It is funded to a total of € 4.5 million for six years (end 2008-mid 2014) by Dutch International Cooperation.

History and future

CoS-SIS is the second phase of CoS. CoS1 (2001-2006) focused on participatory technology development (PTD) in Benin and Ghana. It showed that smallholders can capture only limited benefits from even the best-adapted and appropriate technologies because of their constrained opportunities. Hence CoS1 researchers started to experiment with institutional change (in addition to their agronomic work). Their early results inspired CoS-SIS in that they convincingly demonstrated that institutional change is both important and feasible. CoS-SIS is currently supporting CORAF in implementing its IAR4D strategy with its West African partners.

Personnel

CoS-SIS employs eight post-doc Research Associates (RAs), recruited part-time from national research organisations and universities, and nine African Ph.D. researchers. Some of the RAs are graduates of the COS1 programme. The RAs facilitate Concerted action and Innovation Groups (CIGs) (multi-stakeholder platforms composed of key actors in an agricultural domain) at the district and national levels to experiment with institutional change. The Ph.D. researchers work at community level with groups of local people to analyse constraints and experimentally develop livelihood opportunities. The doctoral research feeds into the deliberations of the CIGs. The work is overseen by National, Regional and International Programme Coordinators, who together form the Programme Management Committee (PMC). Responsibility for each country programme rests with a Programme Management Team (PMT) composed of senior representatives of universities, ministries, R&D organisations, the private sector, NGOs and FBOs. The PMTs and coordinators are

proving to be high-level networkers and important advocates of the institutional change initiated by the CIGs and PhDs.

Domains reflect national priorities

- *Benin*: cotton, oil palm (inter-cropping oil palm and annual crops, and the oil palm seed system) and integrated water management (agro-pastoral dams in the North, and rice production in valley bottoms in the South);
- *Ghana*: palm oil and cocoa (work in the domain of small ruminants ended when the RA was promoted to another location by his home organisation);
- *Mali*: integrated water management, integration of crop and livestock production (both in the Office de Niger), and shea butter (*karité*).

Key activities

- Identifying key constraints that specific categories of smallholder farmers and processors experience when trying to improve their livelihoods and incomes through productive or value adding activities.
- Identifying and researching the institutional reasons for the constraints at the local and higher system levels.
- Identifying key actors, networks and mechanisms that maintain the constraints, as well as entry points for action to by-pass, or transform the institutional context to overcome them.
- Assembling multi-stakeholder platforms of key actors who can be expected to engage in institutional change in their respective domains.
- Enabling platform actors to experiment with institutional arrangements.
- Institutionalising achievements in university curricula, the programmes of research institutes, government policies, the structure of agricultural industries, and arrangements among enterprises and services and in value chains.
- Researching the processes of change and the work of the CIGs by means of real-time monitoring and a form of modified causal process tracing, based on two declared theories of change (intervention theory focused on internal and external activities and relationships of the CIGs; and power theory, focused on networks that have power to change or maintain institutional contexts linked to each domain).
- Ensuring that the outcomes of the action research are published and disseminated through international scientific media, and shared with local, national, and regional government agencies and political decision makers.

Short biography

Rolland H. Yemadje was born on March 3rd, 1982 at Cotonou, Benin. He completed high school in 1999 at the college Martin Luther King, Benin and started his study at the Abomey-Calavi University, Benin. He successfully obtained the 'Diplome d'ingenieur agronome' with a natural resources management minor in 2004. Part of his undergraduate teaching included the role of mycorrhizal symbioses in forest and agro-ecosystems. From 2005 to 2006, after the 'Diplome d'ingenieur agronome', he worked as extension agent, being responsible for activities in the field of crop production at the Association Interprofessionnelle du Coton (AIC) on the Adja plateau. In 2005, he obtained a fellowship from a Flemish project at the Faculty of Agronomic Sciences in Benin to attend a training in the Laboratory of Applied Physical Chemistry, at the University of Ghent (Belgium) where he focused on biological Nitrogen fixation of 25 varieties of soybean using the natural abundance method. In 2007, he was offered scholarships by the French Institut de Recherche pour le Developpement and the Agence Universitaire de la Francophonie to study for a Master of plant biology at the University of Dakar (Senegal). He completed in 2008 with a master thesis entitled: Arbuscular Mycorrhizal Fungi in the rhizosphere of cowpea in agro-ecological systems of Benin. This is where the idea of pursuing a doctoral study was raised. In the same year his research won the best poster presentation award at the 13th Congress of the African Association for biological Nitrogen fixation in Tunisia. Finally, Rolland went for higher challenges and started, in 2009, his PhD program at Wageningen University in the Netherlands, in the departments of Soil Quality (SOQ) and Technology and Agrarian Development (TAD), within the CoS-SIS programme, which aimed to address institutional constraints for smallholder farmers' food security. As a soil biologist he was interested in mycorrhiza while he came across land tenure issues as important constraints for soil fertility restoration. This thesis reflects his newly developed research philosophy. Rolland builds now an interdisciplinary curriculum which bridges between social sciences and natural sciences. His immediate career goal is a post-doc teaching and research position to contribute to knowledge generation for African agriculture development. Rolland is married with Marina Alinde and his children (Ornelia and Nathan) living in Montreal, Canada.

Publications

Journal articles:

Yemadje, R.H., Crane, T.A., Vissoh, P.V., Mongbo, R.L., Richards, P., Kossou, D.K. & Kuyper T.W., 2012. The political ecology of land management in the oil palm based cropping system on the Adja plateau in Benin. NJAS - Wageningen Journal of Life Sciences, 60-63**,** 91-99.

P. Houngnandan, Yemadje, R.G.H., Kane, A., Boeckx, P. & Van Cleemput, O., 2009. Les Glomales indigènes de la forêt claire à *Isoberlinia doka* (Craib et Stapf) à Wari-Maro au centre du Bénin. Tropicultura, 27, 2, 83-87

Houngnandan, P., Yemadje, R.G.H., Oikeh, S.O., Djidohokpin, C.F., Boeckx, P. & Van Cleemput, O., 2008. Improved estimation of biological nitrogen fixation of soybean cultivars (*Glycine max* [L.] Merril) using ^{15}N natural abundance technique. Biology and Fertility of Soils, 45, 175-183

Yemadje, R.H., Crane, T., Mongbo, R.L., Saïdou, A., Azontonde, H.A., Kossou, D. & Kuyper, T.W., submitted. Revisiting land reform: land rights, access and soil fertility management on the Adja Plateau in Benin. International Journal of Sustainable Agriculture (IJAS)

Scientific reports:

Yemadje et al, 2009 Innovation development for sustainable soil fertility management: The case of oil palm belt, South-Benin. Wageningen: Wageningen Agricultural University, 30p.

Yemadje R., (2008), "Biodiversity of endomycorhiza in *Vigna unguiculata* rhizosphere" University of Senegal (Msc report)

Yemadje et al (2006) Evaluation of the symbiotic nitrogen fixation of 25 cultivars of soya (*Glycine max* (L.) Merr.) by the method of natural abundance. Technical report to Flemish Inter-university Council

Yemadje R., (2005) Gender and dams valley management in the municipality of Bantè in Benin. 19p Technical report to 'projet GGPI'

Yemadje R., (2004), "Contribution to the sustainable management of Benin forest: Biodiversity of endomycorhiza of *Isoberlinia doka* (Craib & Stapf) in various agro-ecosystems of the protected forest of Wari-Maro in the Northen Benin " UAC-BENIN (Agricultural engineer thesis dissertation)

Yemadje R., (2004) Characteristics of *Isoberlinia doka* (Craib & Stapf) seeds and biodiversity of endomycorhizas under *Isoberlinia doka* (Craib & Stapf) in the protected forest of Wari-Maro in Benin. Technical report to 'projet d'aménagement des massifs forestiers de Wari-Maro'.

Yemadje R., (2003) Shared and sustainable management of agricultural and natural spaces on the periphery of the urban centers. Technical report to 'projet ECOCITE'.

PE&RC PhD Training Certificate

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities).

Review of literature (4.5 ECTS)

- Innovation development for sustainable soil fertility management: the case of oil palm belt; South –Benin

Writing of project proposal (4.5 ECTS)

- Soil fertility management and land tenure in oil palm belt; South-Benin

Post-graduate courses (6.5 ECTS)

- The CoS SIS Introduction course; CoS SIS programme (2009)

Laboratory training and working visits (4.2 ECTS)

- Carbon, Nitrogen and Phosphorus analysis in soil and plant; Laboratoire des Sciences du Sol, Eau, INRAB au Benin (2011, 2012)

Deficiency, refresh, brush-up courses (3 ECTS)

- The methods, techniques and data analysis of field research (2009)
- Innovation management and cross-disciplinary design (2009)
- Property rights, natural resources and conflict (2013)

Competence strengthening / skills courses (4.5 ECTS)

- English proficiency course for TOEFL; WGS (2009)
- Competencies for integrated agricultural research; WGS (2009)
- Project and time management; WGS (2009)
- PhD Competence assessment; WGS (2009)
- Academic writing course; WGS (2013)

PE&RC Annual meetings, seminars and the PE&RC weekend (0.9 ECTS)

- PE&RC Weekend (2013)

Discussion groups / local seminars / other scientific meetings (5.1 ECTS)

- KTI Lunch seminar (2009-2013)
- CoS SIS Research proposal meeting (2010)
- The CoS SIS small international workshops on PhDs chapters (2010-2012)

International symposia, workshops and conferences (9 ECTS)

- NPT/NUFFIC/Centre for Development Innovation workshop; poster presentation: improving soil quality and crop yield in the oil palm intercropping systems in Adja plateau, Benin (2010)
- The CoS SIS large international workshops; 3 times in Benin, Mali, Ghana (2010-2012)
- International Conference, *Mycorrhizae* in Afrika; poster presentation; Dakar, Senegal (2011)

Supervision of an MSc student (3 ECTS)

- Low-external-input technologies in African farming systems on the Adja plateau in Benin