Cropping systems, land tenure and social diversity in Wenchi, Ghana:

implications for soil fertility management

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Cropping systems, land tenure and social diversity in Wenchi, Ghana:

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Abstract

The original entry point for this study was how to optimize long-term rotation strategies for addressing the problem of soil fertility decline in Wenchi, Ghana. However, as the study progressed over time, it was realized that what we initially interpreted as soil fertility management strategies were closely intertwined with wider issues such as cropping systems, livelihood aspirations and land tenure relations.

Exploration of farmers' soil fertility management practices revealed a link between tenure insecurity among migrant farmers especially, and limited attention for regeneration of soil fertility. The native farmers who own land tend to use rotations involving long-duration crops such as cassava and pigeonpea to improve their soils. In contrast, migrants who depend mostly on short-term rental or sharecropping arrangements, rely more on rotations with short-duration crops such as cowpea and groundnut to improve soil fertility.

A study to examine diversity among farm households and their relevance and implications for orienting action research aimed at combating soil fertility decline revealed that historical, ethnic and gender dimensions of diversity provide additional insights in livelihood patterns and soil fertility management which are relevant for fine-tuning technical and social action research agendas. Relevant differences between farm households result from the interplay between structural conditions and the strategies of active agents.

Five cowpea varieties were evaluated for their grain yield, N_2-fixation and their contribution to the productivity of subsequent maize crop grown in rotation. On both farmer and researcher-managed fields, there were no significant differences in grain yield among the different varieties. Using the ^{15}N natural abundance technique, the proportion of N_2 fixed by the different cowpea varieties ranged between 61 and 77%. On both farmer and researcher-managed fields, maize grain yield after cowpea without application of mineral N fertiliser was higher than maize after maize. Although farmers recognized the contribution of cowpea to soil fertility and yields of the subsequent maize crop, they did not consider this as an important criterion when selecting varieties for use in their own fields. The overriding criteria for selecting cowpea varieties were more related to their early harvest, seed quality in terms of taste and marketability and ease of production (low labour demand).

The performance of maize under different cropping sequences was evaluated in both farmer and researcher-managed experiments. Yield of maize without N application was higher after cassava and pigeonpea compared to that after speargrass fallow, cowpea or maize in both researcher and farmer-managed experiments. A simple financial analysis performed to evaluate the profitability of the various rotational sequences showed cassava/maize rotation to be the most profitable rotational sequence while speargrass fallow/maize rotation was found to be the least profitable. Farmers' preferences for a particular practice were more related to accessibility to production resources and livelihood aspirations.

An action research in the social realm was carried out to develop institutional arrangements beneficial for soil fertility. Initial efforts aimed at bringing stakeholders together in a platform to engage in a collaborative design of new arrangements were stranded mainly because conditions conducive for learning and negotiations were absent. The implementation of experimentation with alternative tenure arrangements initiated by individual landowners and tenant farmers too ran into difficulties due to intra-family dynamics and ambiguities regarding land tenure. Further investigations to find out how ambiguities could be tackled, revealed that the local actors themselves had worked towards institutional arrangements to reduce ambiguities. However, there is still considerable scope for further development of these self-organised innovations. The study stresses the need for continuous diagnosis and exploration in action research in order to steer research in a relevant direction.

Preface

This study was carried out within the framework of the Convergence of Sciences - Inclusive technology development for better soil and crop management, being implemented by the University d'Abomey-Calavi, Cotonou, Benin, University of Ghana, Legon, Ghana and Wageningen University, Wageningen, The Netherlands with funding from the Interdisciplinary Research and Education Fund (INREF) of the Wageningen University; the Directorate General for Development Cooperation of the Dutch Ministry of International Affairs (DGIS); and the FAO's Global IPM facility (GIF). I am very grateful for the financial support from the funding institutions.

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Dedicated to the hardworking farmers at Asuoano, Beposo and Droboso who collaborated in the study

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CHAPTER 1

General Introduction

1.1. Background

Agricultural research to improve soil fertility in sub-Sahara Africa has not had much impact on improving the livelihoods of most of the small-holder farmers living in this part of the world (Bie, 2001; Brader, 2002; Stoop, 2002; IAC, 2004). This has been blamed on the use of wrong model for the generation and diffusion of agricultural technology (Chambers and Jiggins, 1987; Stoop, 2002). In the transfer of technology (ToT) model of agricultural research, scientists largely determine research priorities, develop technologies in a controlled environment and then hand them over to agricultural extension to transfer to farmers (Chambers and Jiggins, 1987). These practices are not fully informed by the views and the needs of the users (i.e. the resource-poor farmers), who are the ultimate clients of the research. The transfer of technology approach relies almost exclusively on technical and economic perspectives while neglecting social and institutional issues (Röling, 1994, 1997). Instead of targeting technologies to meet the needs, aspirations, circumstances and capabilities of the local farmers, often standardised technologies are disseminated to diverse groups of farmers. Technology development and adaptation have often failed to recognise farmers as both a potential source of information about their production environments and cropping systems, and a source of innovation suitable for these environments (Richards, 1985; Hall and Clark, 1995).

Several authors (Röling, 1994, Scoones and Thompson, 1994; Millar, 1994; Hall and Clark, 1995; Stoop, 2002) have argued for a paradigm shift in research and extension. They call for approaches which do not only consider farmers simply as end-users of technologies but equal partners in research and development. Some authors (Pretty and Chambers, 1994; Millar, 1994) have advocated for an interactive and collaborative learning action research with a new role for researchers and extensionists as facilitators and catalysts.

Over the past decades much effort has been invested to improve upon the conventional research and technology transfer system, for instance through farming systems research (FSR) (Collinson, 2000) and participatory approaches, including participatory technology development (PTD) (e.g. Jiggins and de Zeeuw, 1992; van Veldhuizen et al., 1997) by positioning farmers and local communities as active partners and co-researchers in a problem solving process. However, such cooperation remains far from optimal since both FSR and

PTD often fail to analyse systematically the interactions between the technical and social dimensions of problems, and/or translate these into solutions that are both technically and socially viable. In both FSR and PTD, it was recognised that the uptake of promising technologies can be influenced greatly by the availability and / or functioning of institutions such as input supply system, credit, land tenure and marketing. However, such socio-organisational arrangements were regarded as conditions that enhance or constrain adoption of promising technologies instead of being regarded and treated as an integral component of innovation (Leeuwis and Van Den Ban, 2004). Innovation is increasingly being seen and regarded as consisting of a balanced whole of 'hardware' (technology), 'software' (human mindsets and modes of thinking) and 'orgware' (new rules, market arrangements, forms of organisation) (Smits, 2002; Geels, 2002).

In comparison with most areas where the green revolution took place, most part of sub-Sahara Africa is risk prone, agriculture is mainly rain-fed with limited opportunities for irrigation and marked with high diversity (Reijntjes et al., 1992; Stoop, 2002). Erratic rainfall patterns with wide variations within and between years can pose significant variation in farming conditions. Besides the diversity in agro-ecological conditions, variability also exists among farm households in most parts of sub-Sahara Africa where agriculture is only one component of several activities of farmers' livelihoods which may include trading, food processing, and artisan work among others. Such variations among farm households may be due to structural factors and conditions such as access to resources (land, labour, input and credit) and different priorities (food security, cash income generation and risk reduction). Another source of diversity among farm households which may stem from active human agency and strategy have been labelled as 'farming styles' and 'livelihood strategies' (Long, 1990; Van der Ploeg, 1994; Vanclay et al., 1998). Thus the heterogeneity among farm households and farming conditions makes it difficult to develop uniform technology packages that can cover large homogeneous recommendation domains.

1.2. Convergence of Sciences Project

In the Convergence of Sciences approach, it is argued that in order to make an effective contribution to science, there is the need for interaction among societal stakeholders (including farmers) and scientists and also among scientists from different disciplines (see Appendix). This idea of convergence between scientists and societal stakeholders is in line with the principle that innovation is the emergent property of the interaction among stakeholders in agricultural development (Engel and Salomon, 1997). Such convergence between scientists' and farmers' knowledge and experience could be achieved through sustained and continuous interactions between them. Different scientists from both natural and social science disciplines must collaborate and integrate their work because innovation has technical, social-economic and institutional dimensions.

In this approach, we are not simply interested in 'appropriate' technology but also in changing the boundaries and conditions that affect the space for innovation and change. Effective innovations consist not only of novel technical devices, methods and practices, but also of new social arrangements (e.g. new land tenure arrangements, new marketing channels, new ways of mobilising labour) (Leeuwis and Van Den Ban, 2004). This requires that we work towards new forms of institutional arrangements, new rules, market arrangements etc., not only at the field or farm level, but also at higher levels since innovation emerges from a multi-stakeholder process. Such developments in both technical and socio-organisational realms could influence each other in co-evolution of technology and society (Geels, 2002).

1.3. Description of study site

The study was conducted in the Wenchi district ($7^{o}27$ and $8^{o}30$ N, 1^{o} and $2^{o}36$ W) in the forest-savannah transitional agro-ecological zone of Ghana. Ghana which is located in the west coast of Africa, with a population of about 20 million (Year 2000 census) occupies an area of about 238,533 square km of which about 57 % is agricultural land (MOFA, 1991). The country can be divided into five distinct agro-ecological zones namely (i) rain forest; (ii) the forest-savannah transition; (iii) the Guinea savannah; (iv) the Sudan savannah; and (v) the

Coastal savannah. These zones are characterised by distinct rainfall regimes and as a result support specific crops.

The relief in the Wenchi area is gently undulating to flat. The soils, which are mainly Lixisols, are mostly fragile, with shallow top soils underlain with compact concretions and impermeable iron pans (Asiamah et al., 2000). The geology consists of the Voltaian formation occupying most of the southern and the northern sections of the district. It consists of a series of shales, mudstones, sandstones and limestones.

Temperatures are relatively high with monthly mean of about $30^{o}C$. Rainfall starts in April and ends in November with a dry spell in August. The rainy season is followed by a long dry season from November-April. The annual rainfall is about 1300 mm with about 107 rainy days.

Wenchi district which has a total population of 166,449 (Year 2000 census) is ethnically diverse with about 20% of the population being migrants from the northern part of Ghana and neighbouring Burkina Faso. About 33% of the population is involved in Agriculture. The Akan speaking Bonos, who are the indigenous inhabitants, have usufruct right in land by virtue of being members of the landowning families. Migrant farmers, however, access land for farming through one of the following arrangements; renting, sharecropping and *taungya* (an arrangement whereby the forestry service commission gives out land to prospective farmers to grow their food crops who in turn grow and tend trees for the commission).

1.4. The structure of the agricultural sector in Ghana

The Agricultural sector is the dominant sector in the Ghanaian economy in terms of its share of Gross Domestic Product (GDP), employment and foreign exchange earnings. In 2003, the sector contributed about 39.2% to GDP and accounted for about 46.1% of foreign exchange earnings (ISSER, 2004). In Ghana, the agricultural sector is often categorised into 5 sub-sectors namely: crops other than cocoa (61% of agricultural GDP), cocoa (14%), livestock (7%), fisheries (5%) and forestry (11%) (MOFA, 1997). The non-cocoa crop sub-sector includes: cereals (maize, rice, sorghum and millet); root and tubers (cassava, yams and cocoyam); industrial crops (tobacco, cotton, kola nut, oil palm, rubber, groundnut and copra);

horticultural crops (pineapple, mango, chilli pepper, ginger, lime and orange) and other crops (plantain, banana, bean, tomato etc).

It is estimated that the small-holder farmers who use mainly manual labour and minimal external inputs contribute about 80 % of the total agricultural production (MOFA, 1997). Mineral fertiliser usage in Ghana estimated to be about 6 kg/ha across a wide variation of crops, is one of the lowest in sub-Saharan Africa (MOFA, 1997). In the traditional farming system, particularly in the food crop farming, land preparation involves slash and burning. Usually several crops are planted on the same piece of land, probably to avoid the risk of total crop failure. After cultivating the field for 1-3 years when yields are declining, the fields are abandoned and left to fallow for several years. The abandoned land is generally rejuvenated through natural regeneration of vegetation. The longer the rest period the higher the fertility regenerated. However, with increasing population pressure, the fallow period has been shortened thereby making it increasingly difficult to fully restore the fertility of the abandoned land before reverting to cropping.

1.5. Constraints to crop productivity

Except in the valleys, most Ghanaian soils are old, and strongly leached; the greater proportion of the original nutrients in the rocks from which they were formed has been lost (Nye and Stephens, 1962). The predominant clay in the soils is kaolinite which has low cation holding capacities.

The two most commonly deficient nutrients in most Ghanaian soils are nitrogen (N) and phosphorus (P). These deficiencies are more pronounced in the Savannas where the organic matter content is low and the annual bush fires further prevent the build-up of organic matter.

The soils in most part of the country, particularly in the forest savannah transitional zone and the three northern regions are sandy in texture, have low effective water retention capacity, and nutrients leach easily if not well managed. This has resulted in widespread soil impoverishments in these areas, particularly in areas where the soils have predominantly light textured surface horizons with clay pans appearing in shallow depths (MOFA, 1998).

Agricultural technologies developed to solve farmers' problems are not in many cases applicable to their particular circumstances and farming systems. Variability in rainfall, inaccessibility to market and low price paid for most agricultural produce do not encourage the use of mineral fertilisers.

With the trade liberalisation, the Ghanaian farmer has been compelled to compete against cheap imports from Europe and the United States of America, many of which are produced under highly subsidized conditions. For instance cheap rice imports from United States is not only collapsing the local rice industry in Ghana but also beginning to have a substitution effects on locally produced foods like cassava and maize. This is compounded by the increasing costs of inputs at the farm level due to structural adjustment programmes that have removed subsidies and increased supply costs due to the deterioration conditions of rural infrastructures. For instance, in 2002, whereas a metric tonne of urea cost about U.S. $90 FOB (free on board) in Europe (Sanchez, 2002), the same quantity cost a Ghanaian farmer about U.S. $308 at the farm level (ISSER, 2005). Gerner et al. (1995) demonstrated that an increase in the price of fertiliser without a corresponding increase in the price of the produce reduces the profitability of using fertiliser and hence the demand for fertiliser.

Most farmers, especially small-scale farmers, do not have access to formal credit and therefore cannot afford to buy mineral fertilisers even where it has been demonstrated beyond doubt that it is profitable to do so (Obeng et al., 1990). Most of the credit obtained by farmers for their farming activities is from the informal sector with interest rates ranging from 30 to 100%.

Institutional factors such as property rights and land tenure also affect agricultural production in Ghana (MOFA, 1998). In most farming communities, land tenure systems do not favour migrant farmers with negative consequences for the entire society. Limited tenure security often undermines incentives for farmers to invest in their lands. For instance, farmers with limited tenure security are unlikely to adopt soil fertility management practices with long gestation period.

1.6. Farmers' strategies for soil fertility regeneration

The traditional farming system in Ghana depends on natural soil fertility regeneration through the extended fallow system and little on chemical fertilisers (Nye and Stephens, 1962). This system allowed build up of the most limiting nutrients, P and N, in more available forms. The longer the fallow period, the higher the level of fertility generated. However, population pressure and / or the need to increase production have led to a shortening of the fallow periods (Ahn, 1993; Quansah, 1997) resulting in lower crop yields where nutrients are not applied.

Studies in the forest/savannah transitional agro-ecological zone in Wenchi district revealed that farmers, as a response to declining soil fertility have developed certain strategies to improve or maintain the productivity of their soils (Amanor, 1993; Offei and Sakyi-Dawson, 2002). Notable among these strategies are the inclusion of crops such as cassava (*Manihot esculenta* Crantz), cowpea (*Vigna unguiculata* (L.) Walp.) and pigeonpea (*Cajanus cajan* (L.) Millsp.) in the cropping system as a form of rotation.

Grain legume rotations have long been recognized as an important practice for maintaining soil fertility because of their N_2 fixing ability (Peoples et al., 1995; Giller, 2001; Crews and Peoples, 2004). Legume rotations are an important practice for maintaining soil fertility for farmers primarily because grain legumes provide grain and sometimes leaves for food and as a spin off can help in improving fertility through net N contribution (Giller and Cadisch, 1995). It is estimated that under experimental conditions in the field, grain legumes can fix more than 60% of their N requirement (Giller, 2001).

Inclusion of legumes in cropping systems may contribute beneficial effects other than N to soil such as control of erosion, reduced water and nutrient losses and increased cation exchange capacity and nutrient inputs (Wani *et al*., 1991; Giller, 2001). Legume/cereal rotations may also lead to mycorrhizal colonization of cereal roots which may enhance uptake of other nutrients (Wani *et al*., 1991). Other positive effects of legumes on cereals in rotation include decreased pests and diseases of cereals as well as reduction in nematode population (Reddy *et al*., 1986; Francis and Clegg, 1990; Peoples and Craswell, 1992).

Cassava cultivation is often assumed to be associated with soil impoverishment (Hendershott et al., 1972 cited by Nweke et al., 2002; Sitompul et al., 1992; Budidarsono et al., 1998). According to Howeler (1991, 2002), the idea that cassava is a 'scavenger' crop, efficient in nutrient capture and removal, results from the ability of cassava to grow in depleted or degraded soils where other crops fail. Several studies (Putthacharoen et al., 1998; Howeler and Cadavid, 1983; Howeler, 1991, 2002) have demonstrated that cassava actually removes less N and P than most crops per tonne dry product and a similar amount of K. Howeler (2002) argues that cassava yields of less than 10 t ha^{-1} do not seriously deplete the nutrient level of the soil especially if the tops are returned to the soil.

Studies have also demonstrated that cassava easily forms effective association with mycorrhizal fungi for P uptake from low-P soils (Amon and Adetunji, 1973; Yost and Fox, 1979). The mycorrhizal hyphae function as a highly effective extension of the root system and allow the plant to take up P from the soil from beyond the depletion zone surrounding each root.

The inclusion of cowpea, pigeonpea and cassava in the cropping systems as a form of rotation by farmers are not only strategies for restoring soil fertility but also strategies for coping with structural conditions and factors such as inaccessibility to resources such as land, labour, inputs and credits as well as food insecurity and risk of crop failure.

The complexity of farmers' problems which also include institutional issues such as credit, input supply, marketing and land tenure, as well as their in-depth knowledge about soil fertility management, suggest the need to increasingly involve them in the development of soil fertility management innovations suitable for their own environment. The assumption underlying this thesis is that, developing innovations jointly with farmers, using their values, knowledge and expertise through negotiations will not only produce research outcome that is appropriate but also at the same time contribute to changing what is appropriate.

1.7. Aim and outline of the study

The aim of the study is to facilitate the development of soil fertility management innovations among small-holder farmers in the forest / savannah transitional agro-ecological zone in Wenchi. The main focus of the study is to jointly develop soil fertility management innovations with relevant stakeholders using their values, knowledge and expertise through negotiations to produce results relevant to the different sections of the farming community. The specific objectives are:

- To explore farmers’ soil fertility management practices in Wenchi district and understand the social rationale of the different technical practices;
- To explore diversity among farmers in order to orient interdisciplinary action research on cropping systems to meet the needs of different groups of farmers;
- To evaluate the efficacy of different soil fertility management strategies being used by farmers; and
- To understand social and institutional dimensions of innovation and also contribute to the development of new social arrangements as an integral part of innovation.

To achieve these objectives, a diagnostic study was carried out at Asuano, one of the collaborating farming communities to explore together with the farmers, their soil fertility management practices and their relevant social context, with the purpose of grounding the subsequent action research in the needs of the local farming community. The results of this study are presented in Chapter 2. Chapter 3 focuses on a study to explore diversity among farmers for orienting inter-disciplinary action research on cropping systems. Chapter 4 presents results of a study carried out to evaluate productivity, yield and nitrogen fixation of cowpea varieties and their subsequent residual effects on a succeeding maize crop as well as farmers’ criteria for selecting cowpea varieties for planting. In Chapter 5 we present the results of a study carried out to evaluate the productivity of various farmer developed cropping and soil fertility enhancement practices while Chapter 6 reports on action research efforts, which were aimed at developing institutional arrangements beneficial to soil fertility management. Chapter 7 discusses the main findings of the study and its implications for interdisciplinary action research.

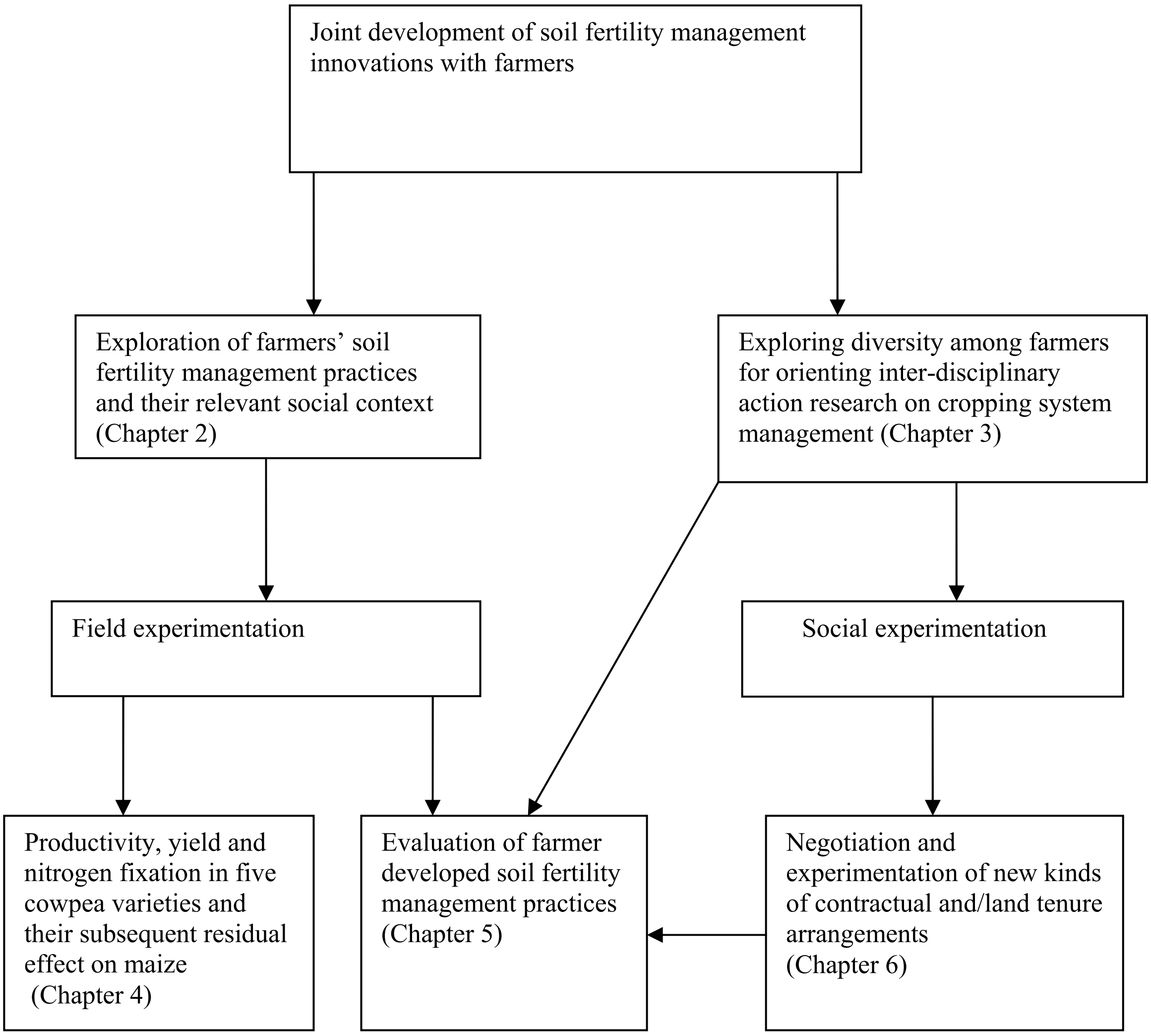

Figure 1 Structure of the thesis

References

Ahn, P.M., 1993. *Tropical soils and Fertiliser Use*. Harlow, UK. Longman.

Amanor, K.S., 1933. Wenchi Farmer Training Project: Social/environmental baseline study: Unpublished report to overseas Development Administration.

Amon, B.O.E. and Adetunji, S.A., 1973. The response of maize, yam and cassava to fertilisers in a rotation experiment in the savannah zone of western Nigeria. Nigerian Agricultural. Journal 10: 91-98.

Asiamah, R.D., Adjei-Gyapong, T., Yeboah, E., Fening, J.O., Apontuah, E.O. and Gaisie, E., 2000. Report on soil characterisation and evaluation at four primary multiplication sites (Manpong, Wenchi, Asuansi and Kpeve) in Ghana. Technical Report No. 200, Soil Research Institute, Kumasi, 91pp.

Bie, S.W., 20 01. The 1990s: An important decade for agricultural research in developing countries. In: ISNAR. Annual report 2000: Reflecting on an important decade for agricultural research in developing countries. The Hague: International Service for National Agricultural Research.

Brader, L., 2002. A study about the causes for low adoption rates of agricultural research results in West and Central Africa: Possible solutions leading to greater future impacts. A study commissioned by the interim science council/CGIAR, FAO, Rome.

Budidarsono, S., Tomich, T.P., Lusiana, B. and van Noordwijk, M., 1998. Profitability Assessment of Transmigration Land Use System, Degraded to Imperata cylindrica Grassland. Southeast Asia Policy Research Working Paper, No. 6, Bogor, Indonesia, 82 pp

Chambers, R. and Jiggins, J., 1987. Agricultural research for resource-poor farmers. Part 1: transfer of technology and farming system research. Agricultural Administration and Extension, 27: 35-52.

Collinson, M. (Ed.), 2000. History of Farming System Research. CABI Publishing, Wallingford, UK.

Crews, T.E. and Peoples, M.B., 2004. Legume versus fertiliser sources of nitrogen: ecological trade-offs and human needs. Agriculture, Ecosystem and Environment, 102: 279-297

Engel, P.G.H. and Salomon, M., 1997. Facilitating Innovation for Development. A RAAKS Resource Box. Royal Tropical Institute, Amsterdam.

Francis, C.A. and Clegg, M.D., 1990. Crop rotation in sustainable production systems. In: C.A. Edwards, R, Lal, P. Madden, R.H. Miller and G. House (Eds), p. 107-122, Sustainable agricultural systems. Soil and Water Conservation Society, Ankeny.

Geels, F., 2002. Understanding the dynamics of technological transitions. A co-evolutionary and socio-technical analysis. Twente University Press, Enschede.

Gerner, H., Asante, E.O., Owusu Benoah, E. and Marfo, K., 1995. Ghana fertilizer privatization scheme: Private Sector Roles and Public Sector responsibilities in meeting needs of farmers. IFDC-Africa, Lome, Togo.

Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems, 2nd edn. CAB International, Wallingford, UK.

Giller, K.E. and Cadish, G., 1995. Future benefits from Biological Nitrogen fixation: an ecological approach to agriculture. Plant and Soil, 174: 255-277.

Hall, A. and Clark, N. (1995) Coping with change, complexity and diversity in agriculture – the case of rhizobium inoculants in Thailand. World Development, 23:1601-1614.

Hendershott, C.H. (Ed), 1972. A Literature Review and Research Recommendations on Cassava, Manihot esculenta, Crantz. Unpublished paper. University of Georgia, Athens, Georgia. Cited in Nweke, F.I., Spencer, D.S.C and Lynam, J.K., 2002. The Cassava Transformation, Africa's Best-Kept Secret, East Lansing: Michigan State University Press.

Howeler, R.H., 1991. Long-term effect of cassava on soil productivity. Field Crops Research, 26: 1-18

Howeler, R.H., 2002. Cassava mineral nutrition and fertilisation. In R.J. Hillocks, M.J. Thresh and A.C. Belloti (Eds.) Cassava Biology, Production and Utilisation. (p.115-147) CAB International, Wallingford, UK.

Howeler, R.H. and Cadavid L. F., 1983. Accumulation and distribution of dry matter and nutrients during a 12-month growth cycle of cassava. Field Crops Research, 7: 123-139.

Inter Academy Council (IAC), 2004. Realising the Promise and Potential of African Agriculture. Inter Academy Council, The Hague, 266 pp.

ISSER, 2004. The state of the Ghanaian Economy in 2003. University of Ghana, Legon, 212pp.

ISSER, 2005. The state of the Ghanaian Economy in 2004. University of Ghana, Legon.

Jiggins, J. and. De Zeeuw, H., 1992. Participatory technology development in practice: process and methods. In: C. Reijntes, B. Haverkort and A. Waters-Bayer (Eds.), Farming for the future: An introduction for Low-External Input and Sustainable Agriculture (pp. 135-162). ILEIA, Macmillan and Leusden, London.

Leeuwis, C. and Van Den Ban, A., 2004 Communication for Rural Innovation. Rethinking Agricultural Extension. Blackwell, Oxford, 412 pp.

Long, N., 1990. From paradigm lost to paradigm gain? The case for actor-oriented sociology of development. European Review of Latin America and Caribbean Studies, 49: 3-32

Millar, D., 1994. Experimenting farmers in Northing Ghana. In: I. Scoones and J. Thompson (Eds), Beyond Farmer First. Rural people's knowledge, agricultural research and extension practice, (pp 160-165). Intermediate Technology Publications, London.

Ministry of Food and Agriculture, 1991. Agriculture in Ghana, Facts and Figures, Accra: PPMED.

Ministry of Food and Agriculture, 1997. Agriculture in Ghana, Facts and Figures, Accra: PPMED

Ministry of Food and Agriculture, 1998. National Soil Fertility Management Action Plan, Directorate of Crop Services, Accra. 159pp

Nweke, F.I., Spencer, D.S. and Lynam, J.K., 2001. The Cassava Transformation. Africa's Best-Kept Secret. Michgan State University Press, East Lansing.

Nye, P.H. and Stephens, D., 1962. Soil fertility. In: J.B. Wills (Ed.), Agriculture and Landuse in Ghana, (pp. 127–143) Oxford University Press, London.

Obeng, H.B., Erbyn, K.G and. Asante E.O., 1990. Fertiliser Requirements and Use in Ghana Consultancy Report, Tropical Agricultural Development Consultancy, Accra, Ghana.

Offei, S.K. and Sakyi-Dawson, O., 2002. Technographic studies on cowpea as a private sector crop in Ghana. Report presented at an International Workshop on the 'Convergence of Sciences' project, 23–29 March 2002, Cotonou, on line available at http://www.dpw.wageningen-ur.nl/forum accessed on 12/09/02

Peoples, M.B. and Crasswell, E.T., 1992. Biological nitrogen fixation: Investments, expectations and contributions to agriculture. Plant and Soil, 141: 13-39

Peoples, M.B., Herridge, D.F., Ladha, J.K., 1995. Biological nitrogen fixation: an efficient source of nitrogen for sustainable agricultural production. Plant Soil, 174: 3-28.

Pretty, J. and Chambers, R., 1994. Towards a learning paradigm: new professionalism and institutions for agriculture. In: I. Scoones and J. Thompson (Eds), Beyond Farmer First. Rural people's knowledge, agricultural research and extension practice, pp 182-202. Intermediate Technology Publications, London.

Putthacharoen, S., Howeler, R.H., Jantawat, S. and Vichukit, V., 1998. Nutrient uptake and soil erosion losses in a Psamment in eastern Thailand. Field Crops Research, 57: 113-126.

Quansah, C., 1997. Approaches to replenishing soil fertility depletion in Ghana. In Proceedings of international seminar on Approaches to Replenishing Soil Fertility in Africa-NGO-perspectives. (pp. 32-40), 3-9 June, 1997. ICRAF HOUSE, Nairobi, Kenya.

Reddy, K.C., Visser, P.L., Klaij, M.C. and Ranard, C., 1994. The effects of sole and traditional intercropping of millet and cowpea on soil and crop productivity. Experimental agriculture, 30: 83-88.

Reijntjes, C., Haverkort, B., Waters-Bayer, A., 1992. Farming for the future: An introduction to Low-External-Input and Sustainable Agriculture. ETC/ILEIA, The Netherlands.

Richards, P., 1985. Indigenous agricultural revolution. Hutchinson and Co. London

Röling, N., 1994. Facilitating sustainable agriculture: turning policy models upside down. In: I. Scoones and J. Thompson (Eds), Beyond Farmer First. Rural people's knowledge, agricultural research and extension practice, (pp 16-32). Intermediate Technology Publications, London.

Röling, N., 1997. "Creating human platforms to manage natural resources: First results of a research program"In A. Budelman (Ed.), Agricultural R andD at the crossroads. Merging Systems Research and Social Actor Approaches (pp. 149-158). Royal Tropical Institute, Amsterdam.

Sanchez, P. A., 2002. Soil Fertility and Hunger in Africa. Science, 295: 2019-2020.

Scoones, I. and Thompson, J., 1994. Knowledge, power and agriculture − towards a theoretical understanding. In: I. Scoones and J. Thompson (Eds), Beyond Farmer First. Rural people's knowledge, agricultural research and extension practice, pp 16-32. Intermediate Technology Publications, London.

Sitompul, M., Setijono, S., van der Heide, J. and van Noordwijk, M., 1992. Crop yields and sustainability of cassava-based cropping systems on an ultisol in Lampung. Agrivita, 15: 19-28.

Smits, R. (2002) Innovation studies in the 21st century. Questions from users perspectives. Technological Forecasting and Social Change, 69: 861-883.

Stoop, W.A. (2002) A study and comprehensive analysis of the causes for low adoption of agricultural research results in West and Central Africa: possible solutions leading to greater future impact: the Mali and Guinea case studies. A study commissioned by the interim science council/CGIAR, FAO, Rome.

Vanclay, F., Mesiti, L. and Howden, P., 1998. Style of Farming and Farming Subcultures: Appropriate concepts for Australian rural sociology? Rural Society, 8: 85-107.

Van der Ploeg, J.D., 1994. Styles of farming: an introductory note on concepts and methodology. In J.D. Van der Ploeg and A. Long (eds) Born from within: practices and perspectives of endogenous development, Assen: Van Gorcum

Van Veldhuizen, L., Waters-Bayer, A. and De Zeeuw, H. .1997. Developing technolog with farmers. A trainer's guide for participatory learning. Zed Books Ltd, London.

Wani, S.P., McGill, W.B. and Tewari, J.P., 1991. Mycorrihzal and common root infection and nutrient accumulation in barley grown on Breton loam using N from biological fixation or fertiliser. Biology and Fertility of Soils, 12: 46-54.

Yost, R.S. and Fox, R.L., 1979. Contribution of Mycorrizae to P nutrition of Crops Growing on an Oxisol. Agronomy Journal, 71: 903-908.

CHAPTER 2

Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: implications for interdisciplinary action research

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Abstract

In the past, farmers in the forest-savannah transitional agro-ecological zone of Ghana relied on the bush fallow system for maintaining the productivity of their farmland. However, in recent years population growth-induced pressure on land has increased and farmers have developed various other strategies for improving the productivity of their farmlands. Such strategies have been identified in the context of an interdisciplinary action research project and include rotations with cassava (*Manihot esculenta*), pigeonpea (*Cajanus cajan*) and cowpea (*Vigna unguiculata*). Using a social science model for understanding technical farming practices, this article explains the differential adoption of these locally developed soil fertility management strategies. It transpires that native and migrant communities are captured in a social dilemma situation, which has negative consequences for soil fertility in that promising practices are not utilized optimally. Based on this research experience, this article concludes with a discussion of the implications for co-operation between natural and social scientists in the context of interactive action research. It is argued, amongst other things, that the essence of such co-operation lies in the critical questioning and influencing of each other's key assumptions and disciplinary research agendas.

2.1. Introduction

The forest-savannah transitional agro-ecological zone of Ghana has a great potential for the production of staple crops, particularly maize and yam. However, the production of these crops appears to be hampered by a low soil organic matter content, which subsequently leads to poor soil moisture relations and to low phosphorus (P) and nitrogen (N) contents.

In the past, resource-poor farmers cultivating food crops in the transitional zone of Ghana relied on the extended bush fallow system for maintaining the productivity of their farmlands (Nye and Stephens, 1962). This system allowed P and N (the most limiting nutrients) to be restored. However, population growth-induced scarcity of suitable farmland has led to the shortening of the fallow period. A study carried out on the cowpea (*Vigna unguiculata*) production system in the forest-savannah transitional agro-ecological zone in Wenchi District revealed that soil fertility decline is of critical concern to the farmers in this zone (Offei and Sakyi-Dawson, 2002). The study showed that one way by which farmers in this area attempt to regenerate the fertility of their farmland is to crop the land to cassava (*Manihot esculenta*) for 18 to 24 months after which period the land – according to farmers – is rejuvenated. However, this assertion is diametrically opposite to the common belief that cassava has a high demand for plant nutrients. Research data quoted by De Geus (1973) indicate that for a tuber yield of 40 tons ha^{-1}, from 85–90 kg N; 27–29 kg P and 232–260 kg K are removed from the soil. Thus in Ghana, where the average cassava tuber yield is estimated at 12.7 tons ha^{-1} (ISSER, 2004), about 27-29 kg N; 8-9 kg P and 74-83 kg K can be removed from the soil. Howeler (2002) concludes that the idea that cassava is a 'scavanger' crop, efficient in nutrient capture and removal, results from the ability of cassava to grow in depleted or degraded soils where other crops fail. He further demonstrates that cassava removes less N and P than most crops per tonne of dry product and a similar amount of K. In addition to cassava, other strategies used by farmers in the regeneration of their soils include the use of legumes such as cowpea and pigeonpea (*Cajanus cajan*) in their crop rotation systems. Pigeonpea is usually cropped to the land over a period of time ranging from 12 to 24 months after which the fertility of the soil is believed to be restored, using earthworm casts as indicator for soil fertility.

This article does not seek to test or explain the bio-physical merits, dynamics and efficacy of these farmer-developed strategies but aims at further exploring farmers' soil fertility management practices and their relevant social context, with the purpose of grounding future action research in the needs of the local farming community.

In this article, innovations and technologies are regarded as consisting of both technical and socio-organizational arrangements and practices. The technical dimension refers to biotic and abiotic factors and practices such as crop varieties, machinery and rotations while the socio-organizational dimensions may involve financial, labour, tenure, knowledge and/or marketing arrangements. These two dimensions are interrelated since both provide the necessary space and conditions for the adoption and diffusion of a particular technology. Thus, one can only speak of a 'complete' technology if there is an appropriate mix and balance between technical devices and socio-organizational arrangements. Starting from these premises, this article seeks to understand the social dimensions of the farmer-developed soil fertility management practices. First, it is shown that despite the fact that most farmers believe in the positive effects of using cassava and pigeonpea rotations for purposes of soil fertility regeneration, these practices are performed by only a section of the farming community. Subsequently, the underlying logic and dynamics of this differential application are explained with the help of Leeuwis and Van Den Ban's model for understanding the social nature of technical farming practices (Leeuwis and Van Den Ban, 2004). We then proceed with a discussion of the implications of these findings for the ongoing action research. Finally, we conclude with a reflection on the broader lessons that can be drawn with respect to interdisciplinary co-operation between natural and social scientists in the context of interactive action research trajectories. Before embarking on this trajectory, however, we first need to further introduce the research methods and approaches applied in it.

2.2. Materials and methods

2.2.1. Study area and population

The study was carried out in Asuoano (7^{o}41' N, 2^{o}06' W), a farming community in Wenchi District, Brong-Ahafo region, Ghana. This area falls within the forest-savannah transitional agro-ecological zone of Ghana. The soils in the area, which developed on Voltaian sandstones, are mainly Lixisols (Asiama *et al*., 2000). These well- drained, friable and porous soils are sandy loams. Nutrients are concentrated in the topsoil organic matter and the soil mineral matter has little capacity to supply or retain nutrients (Adjei-Nsiah, 2002). The rainy season is from April to October with a short dry spell in August. The average annual rainfall is 1271 mm with an average number of 107 rainy days. While the total amount of rainfall seems to decrease slightly over the past 20 years, the total number of rainy days seems to increase slightly over the same period.

The village of Asuoano is about 23 km away from Techiman along the Techiman–Wenchi road. The village is strategically located due to its closeness to Techiman, one of the most important marketing centres in the West Africa sub-region. It has a population of about 760 people and a farmer population of about 270, of which some 25% are migrants. The community is made up of two groups of people: the natives, who are Akans, and the migrant farmers who mainly came from the Upper West region of Ghana. The migrant farmers consist of three ethnic groups: the Lobis, Walas and Dagarbas. As a result of unfavourable climatic and soil resources in the Upper west region of Ghana (which is part of the Sudan Savannah agro-ecological zone) they migrated to the forest-savannah transitional agro-ecological zone where climatic and soil resources are more favourable for food production. There are two groups of migrants: those who settle permanently to farm either by renting land or through share cropping and those who migrate annually from the upper west region to work as farm labourers during the month of January and return in June.

2.2.2. Research approach and methods

The study area was selected after an initial exploratory project study carried out according to the idea and principles of 'technography' (which according to Richards (2001) is an attempt to map the actors, processes and client groups in a technological landscape in such a way that analysts can see beyond the technology itself the problems technological applications are supposed to solve, and to understand what parties and interests are being mobilised in arriving at solutions) revealed the existence of local soil fertility management strategies, some of which seemed to contradict with dominant scientific beliefs (Offei and Sakyi-Dawson, 2002). The key researcher was first introduced to the community by the Agricultural Extension Agent working in the study area. The first meeting offered the researcher the opportunity to introduce himself to the community and to carefully explain his objectives and proposed ways of working in both the diagnostic and subsequent stages of the action research project (Röling et al., 2004). In doing so, the researcher emphasized that he regarded farmers as experts on the local farming system and that he had come to learn from farmers' knowledge and experience with regard to soil fertility, and engage in further collaboration to jointly enhance insights on that matter after an initial diagnostic study.

Subsequently, several community meetings and group discussions were held to further discuss farmers' perceptions and viewpoints about soil fertility management, as well as more general issues like climate, farming system, land tenure and production constraints. Later on, smaller groups were formed who worked on various diagnostic tools such as drawing of a community territory map (to identify the differences in soil fertility patterns), a transect walk (to reveal the diversity of the landscape) and analysis of soil fertility management strategies. The groups were formed by the community members themselves. The bigger group divided themselves into smaller groups based on their knowledge and experiences about the community territory, community organizations and soil fertility management strategies. Membership of each group comprised both men and women. Group discussions (10–40 people) were held in the village centre and/or on farmers' fields. Farmers expressed their ideas by drawing farm maps, pie charts and seasonal calendars and by ranking and scoring.

In addition, two sets of individual interviews were conducted. In the first interview, which involved 40 farmers, the selection of farmers was done by means of stratified sampling. A list of farmers in the village was obtained from the village committee secretary and every tenth name from the list was selected for individual interviewing. The second interview, which involved 38 farmers, was conducted later to look at the farming characteristics of the various sub-communities in the village using a wealth ranking exercise. For this interview 6–10 persons were selected from each wealth category within each sub-community. The first interview was used to collect qualitative data whereas the second interview was used to collect quantitative data.

The individual interviews were semi-structured in nature and served both to get more quantitative data on farm size, household composition and the farming system, and to obtain a better qualitative understanding of the soil fertility management strategies and their underlying rationale. To this end, part of the interviews was more open and informal in nature. In the emerging dialogue and discussions, however, the variables of the Leeuwis and Van Den Ban's model for understanding farmers' practices served as an inspiration for further probing into the matters raised by farmers (Leeuwis and Van Den Ban, 2004).

It must be noted that both group meetings and interviews served not only to 'collect information', but also to create a conducive environment for further co-operation on joint experimentation on soil fertility management strategies with the various sub-communities. Attention was therefore paid to building trust and reaching agreements about issues like goals, role divisions, joint activities and agendas for experimentation.

2.3. Results

2.3.1. Land tenure and cropping system

Traditionally, ownership of land in the community is based on kinship, but vested in the traditional authority in the area which in this case is the chief of Wenchi. Presently, various types of land tenure arrangements were encountered in the community. These include family land inherited through maternal lineage, family land inherited through paternal lineage, spouse's family land, rented or leased land, share cropping (a contract arrangement between tenant and landlord over access to land for the cultivation of food crops), *taungya* (a system where the forestry service commission of Ghana gives out land to farmers to grow their food crops and in turn plant trees for the commission) and personally owned land. Apart from the chief of Wenchi, no individual or family has the right to sell land or lease land on a long-term basis to any investor. However, land can be leased or rented to tenants or used for sharecropping. Land can be leased for a definite period usually ranging from one to three years but occasionally five years depending on the vegetation type and the financial need of the landowner. As transpires from Table 1, the current land tenure system implies that unlike the natives, the migrants who settle permanently cannot own land, but depend on other arrangements such as the renting of land, share cropping and *taungya*. It is worth mentioning that the percentage in each column of Table 1 adds up to more than 100% because there is more than one way in which an individual household can appropriate land for farming.

About 68% of the farmers at Asuoano have total farm sizes ranging between 1.1 and 3.5 ha (Figure 1). The distribution of farm size categories differs among the native and migrant farmers. While about 27% of the native farmers have farm sizes greater than 3.5 ha none of the migrants has a farm larger than 3.5 ha due to the relatively high amount of money they have to pay for renting 1 ha of land.

An indication of the main food crops grown by farmers is given in Table 1. In terms of magnitude, maize is the most important cash crop. Among both the natives and the migrants, maize has the largest plot size of 1.6 and 1.2 ha, respectively (Figure 2). Natives and migrants differ mainly with respect to the cultivation of longer duration crops such as plantain, pigeonpea and cocoyam. For cassava, which also stays on the land for a longer period, the average acreage for natives is about 1 ha, while it is only 0.3 ha for migrants. This

Table 1. Land tenure arrangements among, and most important food crops grown by native and migrants farmers at Asuoano in 2002.

	Natives N=22	Migrants N=16
Land tenure arrangements		
Family land inherited via maternal lineage	68	0
Family land inherited via paternal lineage	36	0
Spouse's family land	27	0
Hired land	23	50
Taungya	9	25
Personally owned land	5	0
Share cropping	0	25
Most important food crops		
Maize	100	100
Cassava	100	88
Yam	100	94
Cocoyam	91	19
Pigeonpea	42	6
Plantain	32	0
Cowpea	23	44
Groundnut	13	14

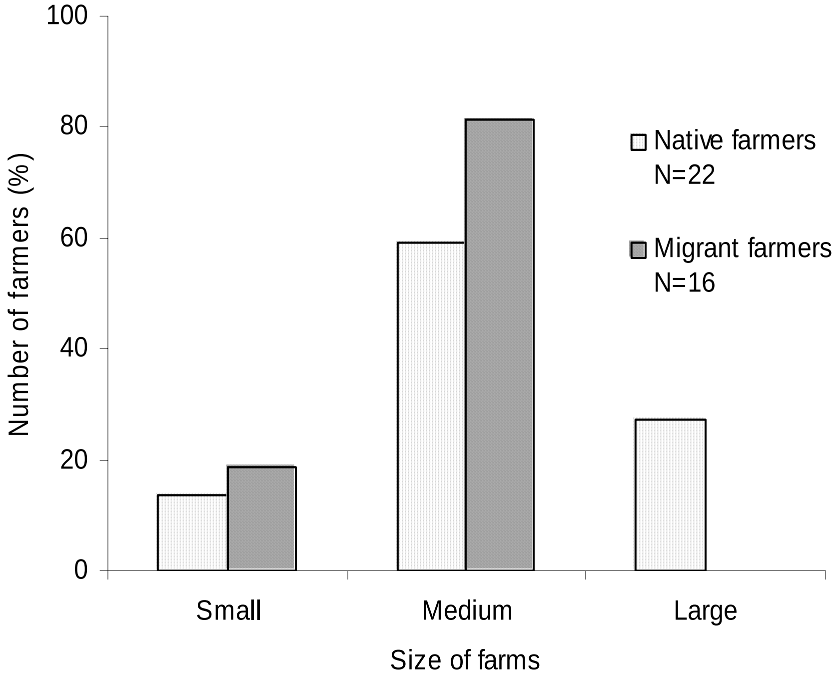

Figure 1. Distribution of farm size among native and migrant farmers at Asuoano. Small: 0-1 ha; medium: 1.1-3.5 ha; large: >3.5 ha.

is closely related to social dynamics around land tenure.

Legumes form an important component in the farming system at Asuoano. While the native farmers cultivate about seven different kinds of legumes, the migrant farmers cultivate only three different kinds of legumes (Table 2). Among the legumes cultivated by the natives, pigeonpea is grown on a larger scale in comparison with other legumes because of its ability to regenerate soil fertility, its low production cost, its tolerance to pests and diseases, its cash income and its food value. It is generally grown on less fertile land and land with problematic weeds such as spear grass (*Imperata cylindrica*). About half of the land allocated to legumes by the migrant farmers is cropped to cowpea. Cowpea is usually grown in rotation with maize to improve the soil.

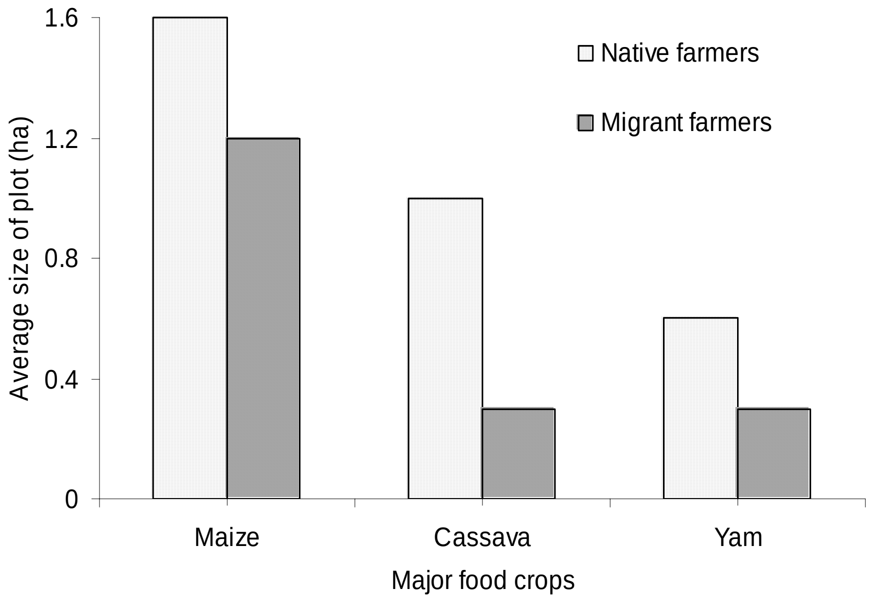

Figure 2 Land areas (ha) allocated to major food crops at Asuoano in 2002.

Table 2. Proportion of land allocated to the leguminous crops grown by native and migrant farmers at Asuoano in 2002

Leguminous crop (%)	Natives	Migrants
Pigeonpea	50	0
Groundnut	20	35
Cowpea	10	50
White kidney bean	10	0
Bambara groundnut	5	15
Mucuna	2	0
Other	3	0

2.3.2. Farmers views on the causes of soil fertility decline

Farmers use several terms to express the fertility status of a soil, whereby the terminology differs from one ethnic group to another (Table 3). For instance, among the Akans and the Walas, loss in fertility means that the soil is tired and therefore must be allowed to rest under bush fallow to regain its lost energy. Farmers use various indicators such as colour, water-holding capacity and soil texture to assess soil fertility. A black soil is considered fertile while gravelly and sandy soils are considered less fertile. Other indicators include the presence of earthworm casts (called earthworm faeces by farmers), growth of crops and weeds, a decline in crop yield and the emergence of certain plant species. For instance, the presence of weeds like *Chromolaena odorata* and elephant grass (*Pennisetum purpureum*) indicate a fertile soil while the presence of weed likes spear grass indicates a less fertile land. Farmers indicated that elephant grass and *Chromolaena odorata* provide shade and a moist environment for the activities of earthworms, which improve soil fertility.

Farmers pointed out five major factors as responsible for the decline in soil fertility: (1) the increasing population has led to smaller farms, which has resulted in the continuous cropping of the same piece of land, (2) the annual bush fires destroy the vegetation and the population of earthworms that improve the fertility of the land, (3) the felling of trees has exposed the land to the direct action of the sun which causes the drying of the land, (4) the continuous cropping of only one crop on the same piece of land without rotating it with other crops as a major factor responsible for fertility decline, and (5) the rapid increase in the monetary value of land as a factor contributing to rapid decline in soil fertility. This monetary value is increased, on the one hand, by the circumstance that families owning land have become more interested in cash along with the greater role of money in the economy at large, and on the other hand by the increasing scarcity of land in view of population increase and migration of farmers from the Upper west region. For instance, people need money to pay for emergency expenditures such as medical bills, funeral expenses, court cases and shelter. Farmers argue that in the older days land had no monetary value and therefore was being given out for share cropping. Hence, landlords could dictate what crop the tenant should grow and also how the land should be managed. However, nowadays landlords have begun renting land to tenant farmers for money. With land now being paid for, landlords can no longer dictate to farmers what type of crops they should grow. In order to maximize profits, tenant farmers began intensive cultivation of the land without sufficient soil fertility restoration measures.

Table 3. Terminology for soil fertility, used by farmers from different ethnic groups at Asuoano

Ethnic group	Soil fertility status	Farmers' terminology	
		Local language	Literal translation
Akans	High	Asaase a srade wo mu	Land with plenty fat
	Low	Asaase no abre	The land is tired
Dagarbas	High	Tengban numo	The land is sweet
	Low	Anua yina	The sweetness of the land is finished
Walas	High	Koole kpenge	The land is strong
	Low	Koole yinge	The land is tired

2.3.3. Indigenous soil fertility management strategies and their use

Farmers mentioned bush fallowing, cassava rotations, planting of leguminous crops such as groundnut, cowpea and pigeonpea as practices that constitute good soil fertility management. Other soil fertility management practices include crop rotations and construction of ridges and mounds. Farmers are of the view that inorganic fertilizers improve the yield of crops but do not improve the soil and therefore cannot be considered as an effective soil fertility management strategy. About 35% of the farmers use inorganic fertilizers (provided on credit by the Food Crops Project of the Ministry of Food and Agriculture) mainly on maize. Farmers cite high cost and risk of crop failure due to the unreliability of rainfall as the reasons for not using inorganic fertilizers. However, farmers were of the view that if they are provided with inorganic fertilizers on credit they would use them. While the farmers consider the use of animal manure as an effective soil fertility management strategy because of its long-term effect on the productivity of the soil, they conceded that they have not been using it because of its unavailability in the community.

Crop rotation in general

The farmers are of the opinion that different crops feed from different depths and on different foods in the soil. So when they rotate different crops on the same soil the yields of their crops do not go down.

Rotation with cassava

Farmers crop a piece of land for 3–4 years to maize and cowpea in rotations and when they observe decline in soil fertility, they crop the land to cassava for 18–24 months after which they resume their maize/cowpea rotation again. Farmers plant a particular variety called 'Boakentemma', which literally means 'able to yield a basketful of tubers'. Farmers claim they prefer this variety owing to its high yielding, its high litter fall as well as its ability to form closed canopy early.

The farmers believe that if maize is grown after cassava, the maize grows faster, looks greener and yields more due to decomposition of cassava foliage incorporated into the soil and pieces of tubers that are left in the soil after cassava harvest. They also mentioned that the roots of cassava are able to penetrate deep into the soil and bring nutrients from the soil to the soil surface through litter falls. Farmers also explained that the cassava canopy as well as the litter protect the soil from the direct action of the sun, increase water infiltration and enhance the earthworm population in the soil. The farmers attributed this beneficial role of cassava to the fact that the variety of cassava that they grow is the spreading type that forms a closed canopy and completely shades the soil from the direct action of the sun. The use of cassava for soil fertility regeneration is not peculiar to only Wenchi. Saïdou *et al.,* (2004) also report of the extensive use of cassava for soil fertility regeneration in some parts of Benin.

Rotation with pigeonpea

After cropping a piece of land to crops like maize, cowpea and yam for about three to four years, farmers intercrop their food crops with pigeonpea during the last cropping year of the cycle. After harvesting the maize and the yam, farmers allow the land to remain under pigeonpea for 18–24 months after which the pigeonpea plants are cut down, burnt and the land cropped to maize or yams.

The pigeonpea canopy is perceived to protect the soil from the direct action of the sun and therefore prevents the soil from becoming hardened. According to the farmers, pigeonpea forms a canopy after one year and shades out obnoxious weeds by suppressing their growth. The farmers also explained that the leaf litter covers the soil, reduces soil erosion, improves infiltration, prevents heating of the soil and enhances earthworm activity. Crops grown on the land after pigeonpea, and especially maize, are perceived by the farmers to look greener, grow faster and yield more.

Bush fallows

When farmers observe a decline in fertility of their soils after cropping for three to four successive years, they allow the land to lie fallow for 2–3 years before they go back and crop the land again. According to the farmers, fallowing the land for 2–3 years allows the land to regenerate its fertility. They mentioned that as the land is allowed to fallow, young trees begin to grow and shade the soil so that the land is not exposed to the direct action of the sun thereby keeping the soil moist all the time. They also reason that during the fallow period the litter of the vegetation on the land fertilizes the soil as it decomposes.

Rotation with cowpea

Farmers rotate maize with cowpea, which has a growing period of about 60-70 days, because of its food value and marketability and to maintain the fertility of their farmlands. According to the farmers, maize grown after cowpea grows faster and yields higher even if inorganic fertilizer is not applied. They mentioned that the nodules formed on the roots contain energy which is released for the growth of the maize when they decompose. Farmers also attribute the yield increase in maize after cowpea to an increase in fertility of the soil as a result of the decomposition of the cowpea foliage that is left on the land after harvest. However, they remarked that if the land is not immediately used for cropping after harvesting the cowpea the fertility of the land is lost since cowpea leaves decompose fast.

Construction of ridges and mounds

Farmers construct ridges or mounds on less fertile plots on forested land. On grasslands, farmers either plough the land and/or construct mounds or ridges. Farmers construct mounds or ridges or plough their land for two reasons. Firstly, the farmers construct the ridges or the mounds to control problematic weeds that invade the land as a result of decline in fertility. Secondly, they construct the ridges or the mounds to improve the productivity of the soil. As they construct the ridges or mounds, the weeds and leaves on the land mix with the soil and fertilize the soil as they decompose.

Farmers reason that the decomposed weeds and leaves when mixed with the soil improve the fertility of the soil and increase the yield of maize planted. According to the farmers, the construction of the mounds and ridges also loosens the soil, which becomes compact after continuous cropping. This allows water to percolate into the soil when it rains. One farmer said 'Mounds are like termite hills. Any crop grown on termite hills does better because it contains a lot of water'. Farmers are of the view that maize planted on ridges or mounds grows faster and yields higher.

While the contributions of legumes such as pigeonpea and cowpea to soil fertility improvement can be explained by their contribution of N to the soil through N fixation, the contribution of cassava to soil fertility improvement is difficult to explain because it is believed to impoverish soils. In comparison with cowpea rotations, pigeonpea and cassava rotations are regarded by both native and migrant farmers as long term soil fertility management strategies.

2.3.4. The differential use of promising strategies

Farmers still generally prefer to regenerate the fertility of their farmland through bush fallowing. Due to population pressure outlined earlier, however, they increasingly resort to other strategies with a remarkable difference between the native and migrant farmers in this respect (see Table 4). While the native farmers widely apply bush fallowing and rotations involving cassava and pigeonpea, we see that migrants mainly use only short-term strategies such as mounding and the planting of short duration legumes such as cowpea and groundnut. At the same time, most of them also continuously crop the same piece of land to maize for two years in both the major and minor seasons in order to get the maximum from the land, thus mining the soil of nutrients.

Table 4. Percentages of natives and migrant farmers at Asuoano in 2002, practising various soil fertility management strategies

Strategy (%)	Native farmers N=22	Migrant farmers N=16
Cassava	82	44
Bush fallow	77	19
Pigeonpea	59	6
Rotation with cowpea/groundnut	18	50
Mounding/ridging	14	100

2.4. Analysis and discussion

This section discusses the main outcomes and implications of our diagnostic study. It starts with an analysis of the differential use of the locally developed strategies that were identified. This is followed by a discussion on implications of the study for the ongoing action research, and some more general reflections on interdisciplinary co-operation.

2.4.1. Explaining the differential use of promising strategies

The cassava and pigeonpea rotation practices, especially, can be regarded as locally developed soil fertility management strategies that only recently captured the attention and interest of individuals within the formal research and extension system. How can we understand the differential use of these strategies across the various communities? More particularly, why is it that migrants do not widely apply seemingly promising rotation practices?

A model for understanding farmers' practices

In our analysis we made use of Leeuwis and Van Den Ban's model for understanding farmers' practices (Leeuwis and Van Den Ban, 2004). According to this model, farmers may have different sorts of reasons for engaging (or not) in specific practices, which can be captured under four composite variables.

1. The variable 'evaluative frame of reference' constitutes the balance between, on the one hand, farmers' knowledge and beliefs regarding the (likely) consequences of specific practices, and, on the other, their valuation of such consequences vis-à-vis a (complex) set of aspirations, resulting in the – implicit or explicit – consideration of 'advantages' and 'disadvantages'. Here it is likely that trade-offs occur between e.g. technical, economic, relational, cultural, political and/or emotional aspirations.
2. The second variable that shapes the application of farming practices is 'perceived self-efficacy' (Bandura, 1977), which centres on the confidence that an individual farmer has in his or her own capacities to perform a practice. Several dimensions of perceived self-efficacy can be distinguished, including perceived availability of skills and competencies, and perceived ability to mobilize resources and accommodate risks.
3. In addition to individual abilities, farmers' practices are also shaped by their assessment of the capacity of their social environment (e.g. agricultural service organizations) to adequately accommodate and support them. This is captured by the variable 'perceived effectiveness of the social environment', which relates essentially to the issue of *trust in others*.
4. Finally, farmers' practices are also shaped by pressures that they experience from other people with whom they relate. This fourth composite variable is labelled 'perceived social pressure', and can be seen to include dimensions such as the desires and expectations that other actors are seen to have regarding the performance of certain practices, the resources (including rewards and sanctions) that such others are perceived to mobilize in order to make farmers comply, and farmers' valuation of the involved expectations, resources and relationships in view of a variety of aspirations.

Much more can be said about e.g. the dynamic interrelationships between variables, the dynamics through time, and the importance of routine and implicit 'reasoning'. For this we refer to Leeuwis and Van Den Ban (2004). Given the idea that technologies consist of technical and social arrangements and involve a network of interdependent actors, it would be a mistake to look only at the (non-)application of specific technical practices (i.e., rotation with cassava and/or pigeonpea) by migrants. Although this serves as an entry point, we need to place such practices in the context of interrelated practices, involving also other actors such as native landlords.

Analysing the differential use of rotations with cassava and pigeonpea

When looking at farmers' evaluative frame of reference regarding cassava and pigeonpea, it is important to note that both native and migrant farmers maintain belief in the positive qualities of these practices for purposes of restoring soil fertility, and have similar views regarding the causal processes at work. Farmers generally associate these kinds of strategies with consequences like better soil fertility levels, increased yield expectations of crops that are planted afterwards, reduced labour requirements for weeding, less need for pesticides, higher income expectations and increased food security provided by pigeonpea and cassava. Although clearly the native farmers have more direct experience, 'technical knowledge' is not the limiting factor on the side of the migrants. Also, there is no indication that there are bottlenecks in terms of availability of technical skills and competencies (as related with perceived self-efficacy).

Zooming in on farmers' aspirations, we see that the consequences mentioned are valued positively by both native farmers and migrants. Thus, when looking at the technical practices and their consequences in isolation, migrants too tend to have a positive attitude towards them. However, in addition, migrants see several obstacles and risks that ensue mainly from the dynamics and practices surrounding contracts between landlords and tenants. Most migrant farmers feel that they cannot raise sufficient money to include cassava and pigeonpea in their cropping system. This relates to the circumstance that migrants cannot own land, while landowners commonly demand immediate payment of rent before renting out land to tenants, amounting often to paying the total rent in advance. Migrants argue that applying cassava and pigeonpea rotations would only make sense if they rented land for longer periods, which is not possible in view of the immediate cash demands by landlords. They also reason that under the present conditions they do not have sufficient security to the land to justify investment in long-term soil fertility management strategies such as cropping the land to pigeonpea. A farmer once remarked: "I will never plant pigeonpea again because when I planted pigeonpea to improve the fertility of my farmland, the landlord asked me to quit the land because one of his sons was coming to farm on the land, when he observed that the fertility of the land had improved". When asked about their awareness of the negative consequences of continuous maize cropping with regard to soil fertility, several migrant farmers answered in affirmative ways and said they preferred to do so because they had to get back the money invested. In response to this, the landowners mention that they are reluctant to rent land to migrants on a long-term basis, because they fear the land will be badly degraded.

In this vicious circle, the fact that migrants need to pay the rent in advance stands out as a central element, which raises questions about the rationale of the landowners in this respect. Here two issues seem relevant. First, it seems that – also in view of the scarcity of land – the indigenous farmers do not look at themselves as being permanently 'in the business of renting out land'. Rather, they rent out land when an immediate cash need arises, for example, in order to pay for occasional happenings such as funerals, marriages and construction works. Secondly, inflation in Ghana is such that landlords prefer to receive the rent agreed upon as soon as possible, before it looses value.

The above shows that the reasons for the limited use of longer-term soil fertility management strategies by migrants are in the social realm. In terms of the model for understanding farmers' practices, we can say that the two efficacy variables are most significant in explaining the limited use. That is, although migrants do – in principle –have positive attitudes (as a result of 'evaluative frame of reference') towards long-term measures, they do not feel able to mobilize sufficient resources to engage in long-term contracts ('perceived self-efficacy'), and feel that the social environment poses obstacles to applying cassava and pigeonpea rotations ('perceived effectiveness of the social environment'). To them, unfavourable community arrangements regarding land tenure and land security are most significant in this respect. In terms of the variable 'perceived social pressure', migrants are afraid of negative sanctions (i.e., losing the land to others who reap the benefits) when they invest in soil fertility. However, it would be wrong to conclude that landlords deliberately apply social pressure to prevent migrants from using long-term soil fertility management practices.

Applying our perspective on technology and innovation, we can say that, although the ‘technical’ practices seem well developed and convincing to both natives and migrants, no adequate social arrangements are in place for migrants to utilize them. In other words, for them the technology can be said to be incomplete, underdeveloped and/or unbalanced.

The above described situation seems to have negative long-term consequences for both the migrant farmers and the landowners, especially when taking into account that migrants cultivate about 40% of the total farmland in the community. Soil fertility seems to fluctuate around lower levels than necessary; landowners get back their land in a degraded state, while migrants have lower yields than locally common and may find it increasingly difficult to rent pieces of land of acceptable quality.

In many ways we can say that we are dealing with a social dilemma situation (Messick and Brewer, 1983) in that a tension exists between both the natives’ and ’migrants short-term individual interests (i.e., getting quick cash, respectively mining the soil) and the collective long-term interest of keeping soil fertility at a reasonable level. A crucial element in social dilemma situations is often a lack of *trust* in each other’s willingness to act in a more co–operative mode, in the social institutions that are in place to bring about such behaviour (Ostrom, 1990; Baland and Platteau, 1996). We can also recognize this in the case of Asuoano. Landowners often do not trust that migrants will maintain the land, and therefore prefer to rent out land only for shorter periods, and against a high price. Migrants have little confidence that landowners will allow them to reap the benefits of investments made in soil fertility, and hence tend to mine the soil. Moreover, it seems that current contractual arrangements do not allow for the making of enforceable agreements in these respects, and neither are they able to handle issues like inflation.

2.4.2. Implications for the ongoing action research

After the technographic study by Offei and Sakyi-Dawson (2002) and initial discussions with ‘the community’, the agenda for the action research was mainly to investigate and further optimize long-term rotation systems including cassava and pigeonpea rotations. This is by means of a combination of farmer-managed and researcher-managed experimentation However, on the basis of the subsequent further exploration of the social dimensions of these promising strategies, it has transpired that it is a mistake to think of the community as a homogeneous category (see also Guijt and Shah, 1998). More specifically, we can conclude that our action research strategy needs to be amended if we want to ensure that migrant communities also benefit from our efforts. Here two directions seem to be possible. The first is to start expanding activities in the technical realm to also include exploration and experimentation on short-term soil fertility improvement strategies such as mounding, and rotation with short duration crops such as cowpea and groundnut. The second is to intensify efforts in the social realm, and engage in the joint design of institutions to help resolve the social dilemma situation described in this article. Although perhaps most significant in terms of its potential impact, this latter strategy will be demanding and complex. It will require the negotiation of and experimentation with new kinds of contractual and/or land tenure arrangements, involving also supporting control and sanctioning systems. In essence, we are talking about institution building and the facilitation of new forms of collective action in an obviously sensitive domain, in which traditional leaders and distinct ethnic communities and their representatives are key stakeholders. As Röling and Jiggins (1998) suggest, this may require the establishment of a multi-stakeholder 'platform' that becomes the focal point for the facilitation of the necessary social learning and negotiation processes.

An important task for the future, then, is to find out whether conditions conducive for a productive learning and negotiation exist, or can be established (see Leeuwis, 2000; Leeuwis and Van Den Ban, 2004). Moreover, it will be necessary to explore what persons may be capable and acceptable to perform facilitation tasks, and whether or not there is any role to play for researchers and extensionists in this respect. We will report and reflect on these matters extensively in a later publication.

At the end of the diagnostic study, an agenda for field experimentation was drawn up with the various stakeholders in the community. The initial agenda was to set up field experiments on individual farmers' fields to evaluate the various soil fertility management strategies such as cassava, pigeonpea and cowpea rotations. However, during discussions with the community on the organizational aspects of experimentation, the migrants suggested the inclusion of other stakeholders in the two nearby communities, Beposo and Droboso, where most of their landlords are located. Subsequently, it was agreed that, instead of establishing research plots on individual farmers' fields, joint learning plots be established in each of the three communities. Both changes, they argued, will contribute to the creation of a more effective context (i.e., a multi-stakeholder platform) for discussing issues related to land tenure arrangements along with technical matters. Moreover, discussions with the farmers about the technical experiments to be carried out in the future indeed resulted in the inclusion of short-term strategies for soil fertility management. Farmers modified the treatments to include other treatments like the performance of maize on lands previously under (1) groundnut/maize rotation and (2) continuous cowpea cropping in addition to the original proposed treatments that included evaluation of maize performance on lands previously cropped to (i) cassava, (ii) pigeonpea, (iii) cowpea/maize rotation and (iv) mucuna/maize rotation. It was also agreed among the various stakeholders to establish two other experiments to evaluate the soil improvement qualities of different varieties of each of the two most important crops used in soil fertility regeneration, i.e., cowpea and cassava. To successfully and jointly carry out these experiments an agreement was reached among the various stakeholders that meetings be held once every fortnight for joint learning on the experimental plots.

2.4.3. Reflections on interdisciplinary action research

This study is part of a project aiming also to enhance co-operation between natural and social scientists. What conclusions can be drawn with regard to this matter?

What we have seen in this paper is how natural scientists' efforts to improve existing technical strategies were combined with a study on their social dimensions, whereby a social science model for explaining farming practices served as an entry point. In order to be able to conduct such a 'hybrid' study, the key researcher – originally trained as a natural scientist – followed several social science courses, and engaged in regular interactions with both natural and social scientists.

From the viewpoint of 'interdisciplinary science' (as distinct from that of the local communities) this way of operating has mainly resulted in a reformulation of underlying assumptions and research questions. The attention for diverse technical practices and their social logic has revealed that the community is not a homogenous whole. More importantly, it has helped to generate relevant dimensions for classifying diversity among farmers in connection with soil fertility; in this case a classification based on land tenure position (associated with ethnic origin), rather than – for example – wealth, gender, farm size or agro-ecological location. In connection with this classification, our views of what were the most relevant problems and questions for research have altered considerably. In the technical sphere, attention shifted at least partly to the potential and limitations of short-term soil fertility management solutions. In the social science domain, it became clear that more detailed insight is needed in the dynamics of land tenure arrangements and their underlying logic, and in the opportunities and constraints that exist for facilitating a process towards the development of new institutional arrangements in the sphere of contracts between tenants and landlords. Thus, we see in essence that – in this action research setting – interdisciplinary co-operation has helped us to generate new questions, that otherwise would not have been addressed.

Working with a 'hybrid' researcher and a multidisciplinary supervision group has proven to be quite advantageous for identifying relevant connections between the social and the technical realm. At the same time, we did not develop in this study some kind of 'transdisciplinary' language that transcended the original disciplines (e.g. inspired by systems theory) but remained largely to look at matters from several disciplinary perspectives. Perhaps as a result of this, the new questions formulated remain quite clearly within either a technical or a social realm. We believe they could – in principle – be further pursued by conventional disciplinary scientists. Although we cannot compare our way of operating with a more 'transdisciplinary' approach, we feel that the co-operation has been beneficial and relevant. Looking at interdisciplinary co-operation as a strategy for sharpening and improving the relevance of 'disciplinary' research questions, therefore, seems worthwhile. Moreover, it is an approach that fits well within the largely disciplinary institutions and reward structures that we all work in. We do not want to make a plea for the reproduction of these structures as such; we rather want to contribute to devising practical strategies for dealing with them and overcoming obstacles to interdisciplinary work.

2.5. Conclusions

We have shown in this article that promising and locally developed technical strategies for redressing soil fertility decline need to be accompanied by adequate social-organizational arrangements if they are to become balanced technologies that can be applied by different segments of the farming population in Wenchi, Ghana. Whether or not such new social arrangements can and will be designed remains to be seen. It requires that social dilemmas and the underlying latent conflicts and lack of trust are somehow overcome, which poses major challenges to stakeholders, researchers, extensionists and those who are in the position to take on a facilitating role.

With respect to interdisciplinary co-operation in an action research context, the experiences reported upon in this article suggest a useful strategy to link natural and social science insights which may – in the early stages – include the following elements:

- exploration of differential farming practices in a certain domain;
- clarifying the social rationale of differential technical practices, leading also to the identification of associated social practices;
- using the available insights to find a relevant characterization of diversity within a community;
- reaching agreement on what segments of the community are supposed to benefit from the action research efforts; and
- critical reflection on earlier assumptions along with the (re)formulation and sharpening of research questions in both the technical and social realm.

References

Adjei-Nsiah, S., 2002. Diagnosing Soil Fertility Management Strategies in Ghana: The Case of Wenchi. Report presented for 'Convergence of Sciences' project at an International Workshop, 29–31 October 2002, Accra, on line available at http://www.dpw.wageningen-ur.nl/forum. accessed on 10/3/03

ISSER, 2004. The state of the Ghanaian Economy in 2003. Institute for Statistical, Social and Economic Studies (ISSER), University of Ghana.

Asiamah, R.D., Adjei-Gyapong., T., Yeboah, E., Fening, J.O., Ampontuah E.O., and Gaisie, E., 2000. Report on Soil Characterization and Evaluation at four Primary Cassava Multiplication Sites (Mampong, Wenchi, Asuansi and Kpeve) in Ghana. Technical Report No 200, Soil Research Institute, Kumasi, 91pp.

Baland, J.M. and Platteau, J.P., 1996. Halting Degradation of Natural Resources: Is there a Role for Rural Communities? Food and Agriculture Organization of the United Nations (FAO), Rome, 423 pp.

Bandura, A., 1977. Self-efficacy: towards a unifying theory of behavior change. Psychological Review, 84: 191–215.

De Geus, J.G., 1973. Fertiliser Guide for Tropics and Subtropics (2nd edition). Centre d'Etude de l'Azote, Zurich, 774 pp.

Guijt, I. and Shah, M.K. (Eds), 1998. The Myth of Community: Gender Issues in Participatory Development. Intermediate Technology Publications, London, 288 pp.

Howeler, R.H., 2002. Cassava mineral nutrition and fertilisation. In: R.J. Hillocks, M.J. Thresh and A.C. Belloti (Eds), Cassava: Biology, Production and Utilisation. CAB International, Wallingford, UK, 115-147.

Leeuwis, C., 2000. Re-conceptualizing participation for sustainable rural development. Towards a negotiation approach. Development and Change, 31: 931–959.

Leeuwis, C. and Van Den Ban, A., 2004. Communication for Rural Innovation. Rethinking Agricultural Extension (3rd edition) Blackwell, Oxford, 412 pp.

Messick D.M. and Brewer, M.B., 1983. Solving social dilemmas. A review. Review of Personality and Social Psychology, 4: 11–44.

Nye, P.H. and Stephens, D., 1962. Soil fertility. In: J.B. Wills (Ed.), Agriculture and Landuse in Ghana, Oxford University Press, London, pp. 127–143.

Offei, S.K. and Sakyi-Dawson, O., 2002. Technographic studies on cowpea as a private sector crop in Ghana. Report presented at an International Workshop on the 'Convergence of Sciences' project, 23–29 March 2002, Cotonou, on line available at http://www.dpw.wageningen-ur.nl/forum accessed on 12 September 2002.

Ostrom, E., 1990. Governing the Commons. The Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge, 280 pp.

Richards, P., 2001. Technographic Studies. Paper presented at the Initiation Workshop on 'Convergence of Sciences' Project, 21–23 February 2001, Accra, on line available at http://www.dpw.wageningen-ur.nl/forum accessed on 13 December, 2002.

Röling, N.G. and Jiggins, J., 1998. The ecological knowledge system. In: N.G. Röling and M.A.E. Wagemakers (Eds), Facilitating Sustainable Agriculture. Participatory

Learning and Adaptive Management in times of Environmental Uncertainty. Cambridge University Press, Cambridge, pp. 283–307.

Röling, N.G., Hounkonnou, D., Offei, S.K., Tossou R. and Van Huis, A., 2004. Linking science and farmers' innovative capacity: diagnostic studies from Ghana and Benin. NJAS – Wageningen Journal of Life Sciences, 52: 211-235.

Saïdou, A., Kuyper, T.W., Kossou, D., Tossou, R. and Richards, P. 2004. Sustainable soil fertility management in Benin: learning from farmers. NJAS – Wageningen Journal of Life Sciences, 52: 349-369.

CHAPTER 3

Exploring diversity among farmers for orienting interdisciplinary action research on cropping system management in Wenchi, Ghana: the significance of time horizons

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Abstract

This article examines different types of diversity among farm households in Wenchi, Ghana, and their relevance and implications for orienting action research aimed at combating soil fertility decline. Previously reported research suggested that cropping systems and indigenous practices affecting soil fertility differed significantly between and among the native population and migrants. These differences were associated with prevailing land tenure arrangements. This paper refines the native / migrant classification by exploring how it is intertwined with aspects such as ethnicity, gender and wealth. The study revealed that historical, ethnic and gender dimensions of diversity provide additional insights in livelihood patterns and soil fertility management which are relevant for fine-tuning technical and social action research agendas. It is argued that relevant differences between farm households result from the interplay between structural conditions and the strategies of active agents. The implication of the study is that action research efforts to design new technology and social arrangements for addressing soil fertility decline must be re-oriented and tailored further to meet the needs and aspirations of particular sub-groups of migrants and natives. Most significantly, it appears that the feasibility of negotiating alternative land tenure arrangements differs among different groups of migrants depending on whether they regard their stay as permanent or temporal.

3.1. Introduction

In the past, traditional soil fertility management depended on the availability of sufficient land to allow for long fallow periods. However, population pressure and the need to increase production have led to a shortening of the fallow periods (Ahn, 1993; Bationo *et al*., 1998). In Wenchi district in the Brong-Ahafo region of Ghana, the shortening of the fallow periods has been worsened by the migration of tenant farmers from the Upper West region in the Sudan savannah agro-ecological zone. Several studies (Adjei-Nsiah *et al*., 2004; Amanor, 1993; Offei & Sakyi-Dawson, 2002) have identified a number of soil fertility management practices being used by farmers. Such practices include rotation of crops such as cassava, pigeonpea and cowpea in the cropping system. Other practices include the use of hoe to till the surface soil, ridging and mounding.

In our previous article (Adjei-Nsiah *et al*., 2004), we found a relationship between cropping system, land tenure and soil fertility management. We showed that natives more often apply long-term rotational practices that included cassava, bush fallow and pigeonpea in order to keep soil fertility at acceptable levels, while migrants tended to resort to short-term practices such as mounding or rotations with short duration legumes such as cowpea and groundnuts. At the same time, migrants tended to crop the same piece of land continuously to maize for two years in both the major and minor seasons in order to get the maximum from the land, thus mining the soil of nutrients. These differences in soil fertility management practices were attributed to differential land tenure arrangements among natives and migrants (Adjei-Nsiah *et al*., 2004). In Wenchi, only the native farmers could own land and hence had relatively secure tenure, while migrants depended mostly on short-term rental or sharecropping arrangements. We argued that the situation had characteristics of a social dilemma situation in which landowners did not trust that migrants would maintain the productivity of the land, and therefore preferred to rent out land only for shorter periods, and against a high price. Migrants, in turn, had little confidence that landowners would allow them to reap the benefits of investments made in soil fertility, and hence tended to mine the soil. On the basis of these findings we suggested that our action research efforts had to be re-oriented to include work on short-term soil fertility management strategies (instead of our earlier focus on longer-term rotations only) and in the social realm had to be complemented with efforts to negotiate and experiment with alternative contractual arrangements.

While our categorisation of farmers into migrants and natives seemed to yield important insights for orienting our action research, we also noted that the situation could be more complex and heterogeneous than portrayed. This is because migrants in Wenchi include different ethnic groups with different histories of migration. Moreover, differences concerning gender, wealth, farming styles and livelihoods remained unexplored, and yet could potentially play an important role (Dharmawan, 2001; Elmhirst, 1996; Gladwin *et al*., 2001; Mosse *et al*., 2002; Van der Ploeg, 1994). In this article we set out to deepen our understanding of diversity among Wenchi farmers by taking into account additional dimensions.

These efforts can be placed in a wider discussion regarding the nature of relevant differences among certain categories of people and the way in which these can be identified. ‘Relevant’, in our context, means that the categorisation of diversity can serve adequately as a basis for developing tailor-made action research activities and strategies related to soil fertility management for different segments of a community. A challenge here is that any community can be segmented in numerous ways (e.g. along variables of age, wealth, gender, education level, household composition, farm size, media preferences, livelihood strategy, etc.), and that it is not evident which categorisation makes most sense for a specific issue. In Farming Systems Research (Collinson, 2000) the emphasis tended to be on classifying farmers on the basis of structural and or demographic variables -such as farm size, soil type, household composition- which could be easily collected in surveys (Mettrick, 1993; Robotham and McArthur, 2001; Tavernier and Tolomeo, 2004). Others have emphasized the importance of cultural dimensions, including ethnicity and gender (Hart, 2000). Implicit in such categorisations is the idea that relevant diversity in human activity is ‘determined’ by structural factors and conditions. As a critique to such modes of thinking, actor-oriented sociologists have emphasized the importance of active human agency and strategy in shaping diversity which was labelled in terms of ‘farming styles’ and ‘livelihood strategies’ (Long, 1990; Vanclay *et al*., 1998; Van der Ploeg, 1994). Leeuwis (1993: 286ff), in turn, has shown that several classifications of diversity can be relevant at the same time, with each classification yielding valid design criteria. He suggested that diversity should be characterised on the basis of an analysis of differential practices and diverging (structural and strategic) reasons that underlie these (Leeuwis, 1993, Leeuwis and Van Den Ban, 2004).

Inspired by the idea that different classifications may yield insights that are relevant to furthering action research interventions, this article explores additional dimensions of diversity than simply ‘natives’ and ‘migrants’. The core question being asked is whether the exploration of differences in ethnicity, gender and wealth leads to new insights on differences in indigenous soil fertility management practices, and what implications can be derived from this for action research aimed at combating soil degradation. The choice for looking at gender, ethnicity and wealth is inspired by specific contextual conditions that became apparent during the diagnostic study (i.e. the presence of migrants from different ethnic groups and with different histories of migration) as well as by findings from other studies focussing on soil fertility management (Tittonell *et al*., 2005). Simultaneously, the exploration leads to improved insight in the livelihood patterns between and among natives and migrants as well as in the relationship between such patterns and their underlying logic on one hand, and land tenure arrangements, cropping patterns and soil fertility issues on the other.

3.2. Materials and methods

3.2.1. Study area and population

The study was conducted in three close communities in Wenchi district of Brong-Ahafo region, namely Asuoano (7^{o} 41’ N, 2^{o} 06’ W), Beposo (7^{o} 41’ N, 2^{o} 07’ W) and Droboso (7^{o} 42’ N, 2^{o} 07’ W). Wenchi district has a total population of 166,641 (year 2000 census) of which about 33% is engaged in agriculture. The three communities, all of which lie along the Techiman-Wenchi road, together have a population of about 3750, the majority of which are farmers (Year 2000 census). The communities are made up of two groups of people: the natives, who are mainly Akan speaking Bonos (80%), and migrants (20%). The migrant population consists of four main ethnic groups namely the Walas (50%), the Dagarbas (30%), the Lobis (10%) and the Mossi (10%). Wenchi is strategically located because first, it is relatively close to Wa and Nandom (about 292 and 373 km respectively from Wenchi), which are the original homes of most of the migrants. Secondly, Wenchi is close to Techiman, which is an important marketing centre for the West Africa sub-region and which serves as a market outlet for their farm produce.

The topography of the area is gently sloping to flat. The soils, which developed over Voltaian sandstones, are mainly Lixisols (Asiamah *et al*., 2000). Most of the soils are fragile, with shallow top soils underlain with compact concretions and impermeable iron pans. They are vulnerable to sheet erosion under intensive cultivation. Rainfall which is bimodal begins in April and ends in November with peaks between June and July and then between September and October. Total annual rainfall is about 1300 mm with 107 rainy days.

3.2.2. Research methods and selection of respondents

Semi-structured interviews served to collect quantitative data on household characteristics, farm size, farming system, tenure arrangements, as well as to obtain better qualitative understanding of the tenure arrangements, different livelihoods and soil fertility management strategies. In addition to the individual interviews, focus group discussions were also held with chiefs, family heads and opinion leaders on issues concerning land tenure and land acquisitions.

We conducted two sets of individual interviews. For the first interview, five farmers each from the three communities who know most of the people in the communities were asked to mention the names of all the farmer households in the community. The native households were then categorised into male-headed households and female-headed households. Subsequently, a stratified sample was selected consisting of 20 male farmers from male-headed households, 20 female farmers from male headed households and 20 female farmers from female headed households. In the case of the migrants, every farmer in the community was interviewed because of the small size of their population. As migrant women do not have their own farming enterprises, only males were interviewed in the migrant categories. Table 1 provides an overview of the distribution of the 265 respondents according to ethnicity and gender.

Table 1. Classification of respondents according to ethnicity and gender (Data set 1)

Ethnicity and Gender					
Bonos N=180			Mossi/Lobis N=16	Dagarbas N=26	Walas N=43
Female farmers in female-headed households	Female farmers in male-headed households	Male farmers	Male farmers	Male farmers	Male farmers
N=60 (33%)	N=60 (33%)	N=60 (33%)	N=16 (100%)	N=26 (100%)	N=43 (100%)

In the second interview, the farmers were selected through a wealth ranking exercise (Grandin, 1988). Fifteen farmers were then selected from each wealth category for interviewing. However, where the number of farmers in a category was less than 15, all the members in that category were interviewed. The interviews were semi-structured and served to collect detailed information on soil fertility management practices and the most important cropping systems. Data on household characteristics, land tenure, farm size, the use of inputs, on-farm and off-farm sources of income and assets were also collected. The two samples overlap to a substantial extent; 80% of respondents for the second round of interviews were also interviewed in the first. Table 2 shows the distribution of the second sample in terms of ethnicity, gender and wealth.

Table 2. Classification of respondents according to ethnicity and gender (Data set 2)

Ethnicity and Gender					
	Bonos N=93		Mossi/Lobis N=16	Dagarbas N=26	Walas N=43
Female farmers in Female-headed households	Female farmers in male-headed households	Male farmers	Male farmers	Male farmers	Male farmers
N= 30 (32 %)	N=0 (0%)	N= 63 (68 %)	N= 16 (100 %)	N= 26 (100 %)	N= 43 (100 %)

The data were analysed statistically using Statistical Programme for Social Sciences (SPSS). Chi square test (χ^2) was used to test for relationships between ethnicity, wealth and gender on the one hand and livelihood patterns on the other.

3.3. Land tenure arrangements

As land tenure arrangements are important for understanding soil fertility management (Edja, 2001; Ondiege, 1996), we briefly outline the different kinds of land tenure that exist in Wenchi before exploring different dimensions of diversity.

There are four main types of holders of land in the Wenchi traditional area. These are:

(1) The chief's holding known as the stool land or the traditional land. This is the land the chief holds in trust for the stool. In Wenchi the stool land is divided into three main zones each being manned by two sub-chiefs known as Abusahene. The Abusahenes (literally meaning "sharecropping chiefs") are the chiefs responsible for the management of the chief's natural resources, especially land in the traditional area.

(2) Family lands. This refers to the lands that belong to individual families. The family land is usually put under an Abusuapanyin (the head in the line of inheriting siblings) who administers the family land and distributes it among the other siblings with land rights. The family land is the land the first native family head was able to acquire and cultivate.

(3) Individual lands. These are the lands that the first native individual was able to acquire and cultivate. Individual lands are also acquired as gifts from parents.

(4) Government lands. These refer to lands under re-forestation by the forestry services division of the Forestry Commission of Ghana. These lands are given out to prospective farmers to grow their food crops while planting and maintaining trees for the commission. This form of arrangement whereby tenant farmers are given land to plant their food crops by the forestry commission while planting and tending trees for the commission is known as *taungya*.

Access to land for farming in Wenchi involves a spectrum ranging from rights acquired through renting to right of use of a piece of land temporarily (Table 3). From the early 1940s, when the influx of migrants began, the traditional council issued land to migrants on the basis of the abusa system or collected annual tributes (Amanor, 1993). This system, which was managed by the abusahene, is still being practised in some part of Wenchi, especially in Buoku area where most of the land belongs to the traditional council. Currently, an annual fee of ¢200,000.00 (US$ 22) or an equivalent of a bag of maize (weighing 100 kg) is paid by tenant farmers to the traditional council. Once this amount is paid, the migrants can clear as much land area as wished in the area allowed.

Since migrants cannot own land in the community, the current land tenure arrangements suggest that migrants can only access land for farming purposes mainly through sharecropping, renting and *taungya*. However, migrants differ in their mode of acquisition of land for farming. For instance, most Walas acquire land for farming mainly through renting and *taungya*, while the other ethnic groups mainly acquire land through renting and sharecropping. In the past, most landowners preferred to give their land out for sharecropping rather than renting it out. Reasons advanced for this include the fact that the amount of

Table 3. Different types of access to land for farming and characteristics of tenure

Type of access	Characteristics of tenure
Rent on individual and family lands	Level of security is low. Tenure duration is usually limited to 1-3 years. Tenant is required to pay advance rent. Limited to only food crops. Land can be accessed by both natives and migrants.
Rent on stool lands	Level of security is high. Duration of tenure is unlimited. Rent is paid at the end of the cropping season either in cash or in kind. Land can be passed on to children after death upon renegotiation. Both food and tree crops can be cultivated.
Sharecropping	Level of security is low. Limited to only food crops. Characterised by conflicts over sharing of crops. Accessible to both natives and migrants.
Gift	Usually given to landless farmers for temporal use for the cultivation of food crops by friends, relatives or landlords. Level of security is medium. Both natives and migrants can access land through gift.
Family land	Level of security is very high but cannot be passed on from fathers to children. Tree crops can be planted only with the consent of other family members. Accessible to only natives
Individual land	Level of security is very high. Type of crop to be cultivated is unlimited. Land can be passed on to children after death. Accessible to only natives.
Taungya	Security of tenure is very high. Type of crop that can be cultivated is limited only to food crops. Both natives and migrants can have access to this land.

money that was earned from the sale of their share of farm produce, was usually higher than the amount that was realised when the land was rented out.

In addition, unlike land renting where the landowner has no right to dictate what crop or combination of crops to be planted, in sharecropping the landowner could determine what crop or combination of crops to be planted. However, because of fear of cheating by migrant farmers over sharing of farm produce, most landlords now prefer to rent their land out to migrants rather than entering into share contracts with them. Some migrant farmers declare only part of the produce obtained for sharing with the land owners, while the rest is hidden somewhere to be taken later by them. Moreover, most migrant farmers harvest part of the produce for home consumption whiles the produce is yet to be shared, often resulting in conflicts.

From the point of view of migrant farmers, it is more profitable to rent land rather than engage in sharecropping because the quantity of farm produce that is usually given to landowners as their share of the farm produce when sold, is usually higher than the money that could have been used to rent the land. Moreover, on rented plots they could harvest part of the farm produce for home consumption any time they wish without having conflict with anybody.

3.4. Livelihood characteristics and strategies among different ethnic groups in Wenchi

Ethnic diversity in Wenchi is the result of migration. Before discussing and comparing some of the major ethnic groups, we briefly outline the history of migration and context in which it took place.

3.4.1. The history and context of migration in Wenchi

The people of Wenchi are made up of a mixed population of different ethnic groups, the majority of whom are Akan speaking Bonos. Other major ethnic groups include the Mos and the Bandas. In addition large numbers of people have migrated from the Upper West region of Ghana, most of whom are Dagarbas, Walas, Mossi and Lobis.

The development of large-scale mechanized farming in the transitional zone in Brong Ahafo from the 1960s has had a tremendous impact on food production in the Wenchi area. The area became an important food-producing zone for the urban markets during this period. The most important crops included maize, yam, cassava, cowpea, groundnut, vegetables, tobacco and cocoa. The improvement of the Kumasi-Tamale road through Kintampo saw Techiman emerging as an important market centre. The establishment of state farms at Wenchi and Branam (both in Wenchi district) and the improvement in road infrastructure at the same period also encouraged the migration of settlers mainly from the Upper west region to Wenchi area in search of employment in the state farms (Amanor, 1993). Those who could not get employment there either rented land for farming or hired themselves out as farm labourers.

Until the 1982-83 bush fires which ravaged the whole country, cocoa remained an important cash crop in the area (Amanor, 1993). An attempt to replant cocoa in the area after the 1983 bushfires failed partly due to the increasing rate of deforestation and the dry season bush fires in the area. With the decline in cocoa production, the migrant labour force, which hitherto worked on cocoa farms, joined the food crop sector. As a result, more forest land was brought into cultivation which attracted more migrants from the Upper West region into the area. In connection with all this, the context in which migration occurred changed significantly over time. Earlier groups of migrants were needed and welcomed in view of labour scarcity on cocoa farms. After the disappearance of these labour shortages and opportunities, migrants became more involved in farming for themselves. More recent groups of migrants, also have the ambition to farm, yet have arrived in a context where land is increasingly becoming (and/or experienced as) a scarce resource. As will become clear below, this shift in context has important implications.

3.4.2. The Akan speaking Bonos

The Akan speaking Bonos are the natives and landowners in the study area. The Bonos practise a matrilineal system of inheritance. This implies that when a migrant man marries a native woman, the children born to them become citizens of Wenchi. However, when a native man marries a migrant woman, the children born to them are not citizens of Wenchi. Intermarriage has occurred between natives and some migrants especially the Lobis, Mossi and the Dagarbas. However, it is usually between native females and migrant males, although a few intermarriages have also taken place in recent times between native males and migrant females, particularly migrant females born and raised in the communities.

Among the natives, husbands and wives farm independently with a large number of them farming on family lands. Where these are limited, they may be supplemented with hired land. The farming activities of most of the male Bonos is oriented towards the cultivation of cash crops, with a majority deriving most of their on-farm income from maize cultivation (Table 4). About 40% of male Bono farmers cultivate more than 2 hectares of land. On-farm income is usually supplemented with income from off-farm activities such as petty trading and other miscellaneous sources including salaried work, palm wine tapping and artisan work.

The Bonos usually employ long-term soil fertility management practices, particularly bush fallow and inclusion of crops like cassava and pigeonpea (Table 4). In comparison with the other ethnic groups, mineral fertiliser use among the Bonos is high with 37% of male farmers applying it (Table 4).

3.4.3. Different migrant groups

Other ethnic groups in the area include the Walas, the Dagarbas, the Lobis and Mossi.

The Mossi and Lobis

The Mossi migrated to Wenchi from Burkina Faso in the early 1940s to work on cocoa farms. Some of the early migrants intermarried with the natives. Intermarriage was one of the means by which a migrant could gain access to land for the cultivation of cocoa. When the male migrants intermarrying native women died, the land reverted back to the women and their children as the Mossi practise a patrilineal system of inheritance. After the 1983 bush fires which destroyed most of the cocoa farms in Wenchi, most of them returned to Burkina Faso. Those who remained in Wenchi took to food crop farming.

The Lobis originally came from Burkina Faso and settled along the Volta River at Sawla in the Northern region of Ghana. They migrated into Wenchi in the early 1950s to work on the cocoa farms. After the 1983 bush fire, most of them joined the food crop sector and engaged themselves in share contracts with their landlords. The Lobis rarely work as farm labourers. They easily intermarry with the natives. Their livelihood styles and the way they relate with the natives indicate that the Lobis are well integrated into the system and regard their stay in the communities as permanent.

There are healthy relationships between the Mossi and the Lobis on the one hand and the natives on the other, due to long-standing relationships that were established two generations ago. The Mossi and the Lobis access land for farming through contractual arrangements, particularly sharecropping. In many instances, the children of the early Mossi and Lobi migrants in the communities still have share contracts with the families of the landlords who hosted their grandparents.

The Lobis and the Mossi rely relatively more on cereals for their on-farm source of income usually supplementing it with off-farm activities such as casual farm labouring. Their cropping system is characterised by yam or cassava-based intercropping usually with maize as the major crop. The long-standing relationships they tend to have with their landlords allow them to use mainly long-term soil fertility management practices such as bush fallowing and rotation with cassava to manage their soils.

The Dagarbas

The Dagarbas come from Jirapa Lambushie and Nadowli districts of the Upper West region of Ghana. The Dagarbas started migrating into the area in the early sixties with the development of large-scale mechanised farming in Wenchi. Some of them came as seasonal migrant labourers while others came to look for employment in the then state farms in Wenchi. Those who could not gain employment with the state farms, however, settled in the communities to engage in share contracts and at the same time offered themselves as farm labourers. The seasonal and new migrants live among the natives and exchange their labour for living accommodation. Once every two weeks they work on the farms of their landlords in exchange for accommodation. Those who settled to engage in share contracts have built houses in the communities. The children of the early settlers have intermarried with the natives. The livelihood styles of the Dagarbas suggest that they regard their stay in the communities as permanent.

Like the Mossi and the Lobis, the Dagarbas also access land for farming mainly through contractual arrangements (Table 4). The Dagarbas also depend relatively more on cereals as their source of on-farm income. The majority of the Dagarbas, in addition to their farming activities, also work as casual farm labourers. About 70% of them do engage in sole maize cropping. About 60% of the Dagarbas apply short-term soil fertility management practices while the remaining 40% rely on long-term management practices to manage their soils. Less than 20% of them apply mineral fertilisers.

The Walas

The Walas come from Wa and its environs in the Upper West region of Ghana. They are the predominant migrants (about 50% of the total migrants) found in the study area. Their migration to Wenchi began in the early 1990s. Before their migration to Wenchi, the early Wala migrants were working in the mining industry in Obuasi, Tarkwa and Prestea. With the fall in the world market price in gold in the early 1990s, most of them were laid off. Subsequently, some of them came to Wenchi and settled at Beposo to farm. When they observed that farming was lucrative in Wenchi, they brought their relatives to stay with them and farm. The new migrants usually start with share contracts during their first two years of farming. When they get money they rent land and later move into the forest to undertake *taungya* farming when they get access to government land. Thus, the major land tenure arrangements used by the Walas include contractual arrangements such as renting and *Taungya.* In comparison with the other migrant groups, the Walas have larger farm sizes (Table 4) even if they do not own land. About 42% of them have farm sizes exceeding 2 ha. Like the other migrant groups, the Walas also depend on cereals for their on-farm income. However, while the other ethnic groups often integrate cassava in their cropping systems, the Walas do not. They have a strong preference for growing short-duration crops like maize and cowpea which have good market and quick return on investment; hence they often engage in sole maize cropping. The Walas in particular do not like the use of long-term soil fertility management strategies such as inclusion of cassava and pigeonpea in the cropping system as a form of rotation. According to Walas, the market for these long-maturity crops is not good, and returns on investment too slow and low. In addition, the Walas argue that they are afraid that when they invest in the soil they will not be allowed to reap the benefit. Only 12% of the Walas apply mineral fertiliser. To manage soil fertility they employ only short-term strategies such as the use of ridges or mounds or rotation with short duration crops such as cowpea. According to the natives, the Walas mine the soil, and this tends to go along with

Table 4. Livelihood patterns among male farmers from different ethnic groups in Wenchi

Livelihood pattern	Ethnicity						
	Bonos N=60	Walas N=43	Dagarbas N=26	Lobis/Mossi N=16	χ^2	df	p
Most important on-farm sources of income (%):					3.9	3	NS
Mainly Cereals with cowpeas	83	91	73	88			
Mainly Root and tubers with pigeonpea	17	9	27	12			
Total	100	100	100	100			
Most important off-farm sources of income (%):					65.4	9	<0.001
Trading	12	9	15	6			
Miscellaneous income sources	27	16	12	6			
Casual farm labouring	–	63	58	25			
Non off-farm income earners	62	12	15	63			
Total	100	100	100	100			
Selected Assets in the communities (%):					15.0	9	NS
House	28	26	31	50			
Vehicles	0	9	–	–			
Vehicles and houses	7	12	4	–			
Non-asset holders	65	53	65	50			
Total	100	100	100	100			
Selected assets outside the Communities (%):					67.0	6	<0.001
Building	–	36	17	13			
Building materials	–	38	10	6			
Non asset holders	100	26	73	81			
Land tenure (%):					111.4	3	<0.001
Own land	85	–	–	–			
Contractual arrangements	15	100	100	100			
Total	100	100	100	100			
Cropping system (%):					9.5	3	0.05
Sole maize	70	91	73	56			
Yam or cassava based intercropping	30	9	27	44			
Total	100	100	100	100			
Farm size (%):					4.2	6	NS
< 1 ha	20	21	23	25			
1 ≥ 2 ha	40	37	50	56			
> 2 ha	40	42	27	19			
Soil fertility management strategies (%):					50.7	3	<0.001
Short term management strategies	12	77	58	19			
Long-term management strategies	88	23	42	81			
Total	100	100	100	100			
Fertiliser use (%):					10.5	3	0.05
Users	37	12	19	13			
Non users	63	88	81	87			
Total	100	100	100	100			

considerable tension between the two groups. Not only the cropping pattern of the Walas is a source of conflict, but also their cultivation practices. Most farmers of Bono speaking origin prefer the use of farming techniques that employ the use of the cutlass in a “minimum tillage” cultivation regime that leaves the root mat of the trees little disturbed. The Walas in particular and the migrants in general prefer to employ farming technologies and practices such as hoe cultivation and the use of ridges and mounds to which they are accustomed. Such practices which hasten the conversion of the forest to savannah (Leach & Fairhead, 2000) are intentionally employed by the migrants and particularly the Walas so that the environment will resemble that of their home of origin in order to enable them to cultivate maize. While the natives claim that such practices predispose the soil to erosion and therefore hasten soil degradation, in the perspective of the migrants such practices do not constitute degradation.

Owing to the way the Walas crop and transform the land, most landowners are reluctant to rent land to migrant tenants, particularly the Walas, beyond 2 years in order to save the land from degradation. Besides soil degradation, sharing of farm produce from share contract arrangements presents another source of conflict between the natives and the migrants (particularly the Walas). While the landowners accuse the migrants of stealing part of the maize before sharing, the migrants maintain that they do not steal but only harvest a part for family consumption.

Another source of tension between Walas and natives is that the Walas usually prefer to either rent a room or put up temporal structures to live in rather than exchanging their labour for living accommodation as the Dagarbas tend to do. According to the Walas, they usually prefer to put up decent accommodation in their communities of origin before putting up buildings in Wenchi. At the end of every harvesting season, the Walas purchase building materials and send them to North. The natives indicate that they do not like that the Walas repatriate income to their communities of origin, while putting up thatch roofed houses in Wenchi.

Their livelihood activities and actions portray that the Walas see their stay in the communities as temporal. When the land in Wenchi is degraded they tend to either relocate to another area or return to the North to re-invest in other businesses. Some of them own motor vehicles which they use to generate income to support their farming activities. The wealthy among them also own motorbikes which they use as means of transport for their farming activities, since most of them have their fields located several kilometres away from settlements. Their livelihood styles and discourses suggest that the Walas have a strong ambition to amass wealth in Wenchi and return to the North to re-invest. The Walas tend to portray their livelihood strategy as the smartest and wisest when compared to other ethnic groups in the communities.

The remarks the Walas make about the other ethnic groups such as the Dagarbas, the Lobis and the Mossi indicate that they look down upon the life style of these groups. They identify strongly with their communities of origin, and find the Lobis pitiful since they are seen to no longer have connections with their roots in Burkina Faso. The Dagarbas are frequently described by the Walas as being lazy and only interested in sharecropping. The Walas, in turn, are branded as cheats and thieves by the natives. From the way the natives talk about the Walas, it appears that they are not liked by the natives and are rated as the most troublesome among the migrant groups. Unlike the other ethnic groups, the Walas rarely intermarry with the Bonos.

3.4.4. The significance of time horizons

When comparing the various ethnic groups we can see that the earlier classification between 'migrants' and 'natives' (Adjei Nsiah *et al*, 2004) has concealed some important differences within the migrant category. While the earlier groups of migrants (Mossi and Lobis, migrating in the 1940s and 1950s; Dagarbas migrating in the 1960s) have developed long-standing relations with the natives and regard their stay as permanent, the Walas have migrated to Wenchi in the early 1990s and tend to look at their stay as temporal. Their ambition to return eventually to their communities of origin may relate to a variety of factors such as active family ties, cultural values and livelihood preferences. In addition, increased scarcity of land in Wenchi, as well as the nature of interactions with natives and early migrants, may reinforce this temporal outlook. In any case, the differences in future horizons and ambitions regarding the stay in Wenchi match important differences in cropping systems and soil fertility management. While the Bonos, Mossi and Lobis tend to have cropping systems that can be expected to partially regenerate soil fertility, the Walas tend indeed to mine the soil, while the Dagarbas seem to take an in-between position in this respect.

Among the various ethnic groups there appears to be considerable tension and stigmatisation between the relatively 'established' groups (especially Bonos, Mossi and Lobis) and the 'outsiders' (the Walas), which is a phenomenon that has been well described in sociology (Elias and Scotson, 1965). Most probably, this tension tends to be fuelled by the relative economic success of the Walas. Although on the basis of our original wealth rankings there did not seem to be a significant difference in wealth between (the males of) different ethnic groups (Table 5), Table 4 suggests that the Walas indeed tend to own more property outside the community. Their relatively large-scale farm operations, combined with their soil mining cropping strategies, apparently allow them to accumulate wealth effectively in their communities of origin.

Table 5. Classification of male respondents according to ethnicity and wealth

Wealth status (%)	Ethnicity				X^2	df	p
	Bono N=60	Walas N=43	Dagarbas N=26	Lobis/Mossi N=16	3.2	6	NS
Wealthy	10	16	11	6			
Average	53	44	39	50			
Below average	37	40	50	44			
Total	100	100	100	100			

3.5. Livelihood characteristics and strategies among female and male farmers in Wenchi

An important difference between the various groups of migrants and the natives is that migrant women do not have their own farming enterprises unless they are widows (Amanor, 1993), while among natives both male and female farmers can have access to land and farm relatively independently, even if they are from the same household. Migrant women are active in agriculture, but work almost exclusively on the land to which access has been secured by male migrants. Migrant males tend to be in charge of farm management and are seen to be responsible for marketing any outputs. Although this resembles some aspects of gender division of labour in the Upper West region, which is the home of origin of most migrants, the situation of migrant women in Wenchi appears to be more vulnerable. According to Amanor (1993: 21-22), "this may relate to the fact that first generation of migrants often joined their husbands without a backup network of relatives on which they could fall on for support, without an independent source of capital to hire land, and they were probably intimidated by predominantly male landowners, chiefs and their husbands from being able to independently negotiate for land". While male and female native farmers may collaborate in various ways (e.g. by providing labour on each others plots) it is clear that men and women are in charge of and responsible for distinct fields and crops. For this reason, our discussions of differences between female and male farmers will focus from here onwards on the Bonos only. Within the female farmer category, we differentiate between females in male headed households and those in female headed households (see Table 1).

3.5.1. Female farmers

About 90% of female farmers cultivate their own land (Table 6). Most of them (about 68% of females in male-headed households and 85% of those in female-headed households) depend on root and tubers as their on-farm source of income. While most women agree that maize production could be more profitable, they experience several obstacles in the cultivation of the crop. Most women feel that they cannot raise the capital needed for getting their fields ploughed and for purchasing inputs such as fertilizers and herbicides. As other studies have shown (Jones and Sakyi-Dawson, 2001), women in Ghana -and in the forest savannah transitional agro-ecological zone in particular (see Asuming Brempong *et al*., 2004) - have limited access to credit. For these reasons most women resort to cultivating root and tubers such as cassava and yams, which require fewer external inputs such as pesticides and fertilisers. Moreover, most female farmers perceive maize cultivation as a risky farm enterprise due to drought sensitivity. They therefore use root and tubers, particularly cassava as an ex-ante risk management strategy (Devereux, 2001). The dependence on root crops such as cassava as the most important source of on-farm income by female farmers may also be related to its relatively low labour demand (Berry, 1993: 187-188). It can also be noted from Table 6 that, trading and other miscellaneous sources such as remittances and food

Table 6. Livelihood patterns of different gender groups among natives farmers in Wenchi

Livelihood patterns	Gender			χ^2	df	p
	Males N=60	Females in male-headed households N=60	Females in female-headed households N=60			
Most important on-farm sources of income (%):				62.0	2	<0.001
Cereals	83	32	15			
Root and tubers	17	68	85			
Total	100	100	100			
Most important off-farm sources of income (%):				3.9	4	NS
Trading	12	25	18			
Miscellaneous sources	27	25	28			
Non off-farm income earners	61	50	53			
Total	100	100	100			
Selected assets in the communities (%):				21.8	6	<0.001
House	30	7	10			
Vehicles	2	–	–			
House and vehicle	3	–	–			
Non-asset holders	65	93	90			
Total	100	100	100			
Land tenure (%):				3.9	2	NS
Own land	85	85	95			
Contractual arrangements	15	15	5			
Total	100	100	100			
Cropping system (%):				41.0	2	<0.001
Sole maize	70	30	15			
Yam or cassava based intercropping	30	70	85			
Total	100	100	100			
Farm size (%):				74.0	4	<0.001
< 1 ha	20	57	93			
1≥2 ha	40	35	3			
>2 ha	40	8	3			
Total	100	100	99			
Soil fertility management strategies (%):				7.0	2	0.05
Short term management strategies	12	8	–			
Long-term management strategies	88	92	100			
Total	100	100	100			
Fertiliser use (%):				13.6	2	<0.001
Users	37	25	8			
Non users	63	75	92			
Total	100	100	100			

processing form the major source of off-farm income for most of the female farmers. About 70 and 85% of the female farmers in male-headed and female-headed households respectively practise intercropping often with cassava or yam as the main crop and usually intercropped with one or two or all of the following: pigeonpea, cocoyam and maize. Most female farmers employ long-term soil fertility management practices. Short-term practices, like mounding and rotation with cowpea and groundnut, tend to be regarded as requiring a mixture of resources such as labour and other inputs like improved seeds and insecticides. In order to reduce dependence on external inputs, particularly insecticides, many female farmers opt for long- term strategies such as rotation with cassava and pigeonpea which require fewer chemicals. Less than 20% of them apply mineral fertilisers.

About 57 and 93% of female farmers in male-headed households and female farmers in female-headed households respectively, cultivate, less than one hectare of land (Table 6). The main factors that result in women cultivating smaller areas are lack of labour to clear landor lack of capital to hire labour (Amanor, 1993). Less than 10% of the female farmers own assets.

It must be noted that several differences exist between female farmers in male-headed and female-headed households. Female farmers in female-headed households have relatively smaller farm sizes, rely more on root and tubers and less on maize, and apply fewer mineral fertilisers. It appears that they face more labour and financial constraints than their counterparts in male-headed households. The latter appear to receive some assistance from their spouses in the form of labour and finance.

3.5.2. Male farmers

About 85% of the male farmers cultivate own land with the minority of them relying on contractual arrangements such as renting and *taungya* (Table 6). Table 6 indicates that about 80% of the male farmers depend on cereals for their on-farm income. This reflects the increasing importance of maize as a major cash crop in Wenchi. Most male farmers indicate that they do not like to depend on root and tubers for on-farm cash income because the return on investment is relatively low and slow.

Most male farmers practise sole maize cropping in contrast to their female counterparts who mainly practise intercropping. This is likely to be associated with the men having more access to land and capital than their female counterparts. However, male Bonos do not crop maize continuously on the same plot, as 88% of them apply long-term soil fertility management practices (Table 6). Of the male farmers 37% apply mineral fertiliser, which is considerably and significantly higher than the proportion of women (especially female-headed households) that applies fertilizer. Forty percent of the male farmers have large farm sizes (exceeding 2 hectares) with only 20% of them cultivating less than a hectare. About 33% and 5% of the male farmers own houses and motor vehicles respectively, which is significantly higher than female farmers.

3.5.3. Differences in wealth according to gender

The above shows that native men and women tend to be involved in agriculture in different ways. Diversity in cropping systems along gender lines seems to be associated with differential wealth positions (see Table 7) Male farmers tend to be more involved in production of cash crops, have larger farm sizes, and apparently are able to accumulate more wealth than women. Female farmers, and especially those in female-headed households, seem to face more constraints with regard to access to labour and money.

Table 7. Classification of native respondents according to gender and wealth

Wealth status (%)	Gender			X^2	df	p
	Male farmers N = 60	Female farmers in male-headed households N = 60	Female farmers in female-headed households N= 60	21.5	4	<0.001
Wealthy	10	0	0			
Average	53	55	33			
Below average	37	45	67			
Total	100	100	100			

3.6. Livelihood characteristics and strategies among different wealth categories in Wenchi

Although we have already touched on issues concerning wealth in connection with gender and ethnicity, we also explored wealth as a dimension of diversity in its own right. Based on wealth ranking and analysis in the communities, the farmers in the study area were categorised into three main groups. Because wealth ranking and gender are intertwined, the analysis below is carried out only among men (Table 8). Men from all ethnicities are included in the analyses since there was no significant relation between our wealth rankings and ethnicity (see Table 5), even if other evidence (i.e. assets accumulated outside Wenchi) suggests that Walas tend to be wealthier in that respect than others.

3.6.1. Wealthy (Relatively well-off) farmers

Wealthy (Relatively well-off) farmers have relatively larger farm sizes, usually exceeding 2 hectares. Farming activities of wealthy farmers are mainly oriented towards commercial maize production. Besides the income from farming, wealthy farmers may have other sources of income including trading, transport, salaried work etc. They have more assets such as vehicles and decent houses. None of the wealthy farmers practise intercropping. In terms of indigenous soil fertility management practices, wealthy farmers do not differ very much from farmers from the other wealth categories. However, a higher proportion of the wealthy farmers (67%) apply fertiliser.

3.6.2. Farmers with average wealth

Most (48%) of these farmers have medium farm sizes (between 1 and 2 ha). They tend to have more diverse means of livelihoods such as petty trading, salaried work etc. Even if to a somewhat lesser extent than wealthy farmers, they depend relatively more on cereals as their on-farm income source than poorer farmers. Their cropping system is characterised by sole maize cropping like the wealthy farmers. About 61% of them use long-term-soil fertility management practices for maintaining the fertility of their soils; in this respect they resemble the other wealth categories. About 25% of them use mineral fertilisers, which is significantly less than wealthy farmers, but more than poor farmers.

Table 8. Livelihood patterns among different wealth categories of male farmers in Wenchi

Livelihood pattern	Wealth Category			χ^2	df	p
	Wealthy N=21	Average N=71	Below average N=56			
Most important on-farm sources of income (%):				8.1	2	0.05
Cereals	100	93	80			
Root and tubers	–	7	20			
Total	100	100	100			
Most important off-farm sources of income (%):				19.4	6	0.01
Trading	19	7	11			
Miscellaneous income sources	48	13	14			
Casual farm labouring	–	30	45			
Non off-farm income earners	33	50	30			
Total	100	100	100			
Selected assets in the communities (%):				84.8	6	<0.001
House only	52	45	7			
Vehicle only	5	6	–			
House and vehicle	38	1	–			
Non-asset holders	5	48	93			
Total	100	100	100			
Land tenure (%):				3.14	2	NS
Own land	29	39	25			
Contractual arrangements	71	61	75			
Total	100	100	100			
Cropping system (%):				8.12	2	0.05
Sole maize	100	93	80			
Yam or cassava based intercropping	–	7	20			
Total	100	100	100			
Farm size (%):				52.4	4	<0.001
< 1 ha	–	3	43			
1≥2 ha	14	48	50			
>2 ha	86	39	7			
Total	100	100	100			
Soil fertility management strategies (%):				0.23	2	NS
Short-term management strategies	38	38	39			
Long-term management strategies	62	62	61			
Total	100	100	100			
Fertiliser use (%):				27.2	2	<0.001
Users	67	25	9			
Non users	33	75	91			
Total	100	100	100			

3.6.3. Poorer farmers

About 43% of farmers in this category have relatively smaller farm sizes usually less than one hectare (Table 8). Their assets are mainly land and labour. According to the key informants who assisted in the wealth ranking exercises, poor farmers are hardly able to feed their children three times a day and are unable to provide schooling for their children. They usually hire themselves out as labourers. In comparison with the wealthy farmers, none of whom depends on root and tubers for on-farm income, about 20% of the farmers in this group depend on root and tubers for on-farm income (Table 8). Twenty percent of the farmers in this category also practise intercropping which is higher than wealthy and average wealthy farmers; this difference, however, is not statistically significant. Fertiliser use among this category of farmers is rare, and significantly less than among other categories

3.6.4. Wealth categories and soil fertility management

As was to be expected, the differentiation according to wealth categories among male farmers in Wenchi shows significant differences in terms of livelihood patterns, especially regarding the composition of on-farm and off-farm sources of income. However, it is interesting to observe that in terms of land tenure arrangements and rotational strategies for soil fertility management, no significant differences were found among the wealth categories. In other ways, however, this classification of diversity is relevant to soil fertility management since it is clear that wealthier farmers tend to make greater use of external inputs for maintaining soil fertility.

3.7. Discussion and conclusion

3.7.1. Additional insight generated on diversity and soil fertility management

All classifications of diversity explored in this article helped to deepen our understanding of soil fertility management. The initial migrant / native classification proved to be too simplistic, and concealed other significant differences. It became clear that there exist various migrant groups which differ with regard to ethnicity, history and context of migration, duration of stay and the nature and quality of relations with the native community. In this complex setting, there is one group of migrants who tends to look at their stay as temporal, which has important implications for soil fertility management. The earlier migrant / native classification implicitly fostered an image from which one could easily infer that the 'migrants' were 'weaker' party or even 'victims' of the situation. After all, they could not own land in Wenchi, depended largely on the natives for access to land, and could not easily invest in the soil since they had no tenure security. While this picture may bear some relevance to some migrants or migrant groups, it has to be refined considerably. It is clear that the oldest migrants especially have managed to build long-standing relationships with the natives, and have relatively secure and long-duration access to land. On the other hand, the latest migrants, even if they do not own land, tend to have large farms and seem to succeed in accumulating wealth on the basis of soil mining.

Our exploration of gender has shown that migrant women seem to be in an extremely dependent –and potentially vulnerable- position since they do not have an independent income from farming. Among natives, the women –and especially those in female-headed households- seem less able than men to generate cash-income and accumulate wealth. Female farmers do use cropping systems and long-term rotation strategies that tend to regenerate soil fertility to some degree, but most likely this needs to be regarded partly as a strategy to deal with limited access to cash, credit and labour. Although (like the Walas) the men tend to produce maize for the market, they combine this with similar long-term rotation systems as women.

The wealth categorisation has been useful mostly as an indicator to underpin the importance of other classifications; between different ethnic groups and gender categories we found significant differences in wealth. Land tenure arrangements and rotational strategies for soil fertility management, however, do not seem to differ significantly among different wealth categories. In a different way, the classification was important to understanding soil fertility management since it showed us that wealthier farmers tend to make greater use of external inputs for maintaining soil fertility.

In relation to the issue of whether differences in soil fertility management are shaped mainly by structural circumstances or by active human strategy, we can see that both play a role. In fact the two seem closely intertwined. The Walas, for example, have an active strategy to accumulate and export wealth to their communities of origin to which they expect to return. But their temporal outlook is likely at the same time to be a response to structural conditions such as how recently they migrated, increased scarcity of land in Wenchi, prevailing land tenure arrangements, and perhaps culturally ingrained meanings and/or expectations from family members. Similarly, female farmers' cropping strategies may best be understood as coping strategies for dealing with 'structural' constraints such as dominant role divisions, limited access to labour, cash and credit, food insecurity and high risks of crop-failure. Nevertheless, while historically-shaped structural and cultural conditions clearly matter, it is clear that they are translated into practices by actively strategising human agents, and that they must not be seen as 'determinants' that influence human behaviour in a mechanical way.

3.7.2. Implications for action research

On the basis of our earlier migrant / native classification (Adjei-Nsiah *et al*., 2004) we concluded that action research should be re-oriented in the technical realm to include exploration and experimentation on short-term soil fertility improving strategies such as mounding, rotation with short duration crops such as cowpea, groundnut etc. In the social realm we suggested looking for institutional strategies through which the time horizon of migrants could be enlarged in order to help resolve the social dilemma situation. Specifically we suggested investing in negotiation of and experimentation with new kinds of contractual and/or land tenure arrangements, involving also supporting control and sanctioning systems. However, this study has shown that important preconditions for such negotiation and learning are absent, at least for many Wala migrants. As several authors have argued (Aarts 1998; Fisher and Ury, 1981; Leeuwis and Van Den Ban, 2004; Mastenbroek, 1997) an important pre-condition for productive negotiations to take place is mutually felt interdependence. Between the natives and Lobis, Mossi and Dagarbas such feelings seem indeed to exist, which suggests that interactive negotiation can be facilitated between them to develop alternative land tenure arrangement. This finding is still relevant as there is still considerable scope for enhancing land tenure arrangements. However, the Walas tend to regard their stay as temporal and therefore they feel far less dependent on the natives. This implies that productive negotiation on alternative land tenure arrangements between natives and Walas will be difficult to achieve, and perhaps must be preceded by strategies that are aimed at enhancing feelings of interdependence on the side of Walas. It may, for example, be that the natives need to better organise themselves collectively so that Walas who want to rent land have no other option than to comply with soil fertility enhancing practices and regulations. Currently, the Walas apparently have no difficulty in accessing land since there are always natives who have an immediate need for cash, and hence are willing to rent out land even if they know this may imply degradation of their soil (see Adjei-Nsiah *et al*., 2004). If natives were better organised to assist each others in times of need, they would be able to take a firmer stance against the soil mining practices of the Walas.

Another implication of the study is that neither the enhancement of short-term soil fertility management strategies, nor the development of alternative land tenure arrangements are likely to be very beneficial to female farmers. Additional investigation is needed in order to assess whether the position of (different categories of) female farmers is indeed as vulnerable as it seems, and to identify new social arrangements through which access to resources may be enhanced.

More generally, we can conclude that in a place like Wenchi, where the population of the farming community is very heterogeneous, designing one technology or social arrangement for enhancing soil fertility management will not suffice. Instead, efforts must be oriented to design a range of technical and social options that will meet the specific needs and circumstances of different categories of people. While current practices and alternative options have been interpreted primarily in terms of 'soil fertility management strategies' by us as scientists, it is important to realise that such a narrow framing reflects predominantly our own professional biases. Our further exploration of diversity has shown that what we see as 'soil fertility management' is closely intertwined with practices, aspirations and strategies in totally different spheres, that must be anticipated in the further development of social and technical options. In order to develop an understanding of relevant diversity in this respect it is necessary and fruitful to explore different dimensions of diversity that are sensitive to the specific context. Even if considerable attention is given to exploration and diagnosis at early stages of action research, there is no guarantee that this will result in sufficient understanding of diversity. Hence, exploration and investigation of diversity must be a continuous process in action research, whereby new issues, dimensions and questions are taken on board as insight progresses. Our continued explorations have shown that it is risky to settle too quickly for one specific categorisation of diversity, even if it seems initially illuminating and useful for targeting and tailoring action research activities. Societal complexity simply cannot always be captured in simple categorisations. Moving beyond such simplicity requires considerable effort and also time on the side of action researchers.

References

Aarts, M.N.C., 1998. Een kwestie van natuur; een studie naar de aard en het verloop communicatie over natuur en natuurbeleid. Published doctoral dissertation. Wageningen Agricultural University, Wageningen.

Adjei-Nsiah, S., Leeuwis, C., Giller, K. E., Sakyi-Dawson, O., Cobbina, J., Kuyper, T.W., Abekoe, M. and Van Der Werf, W., 2004. Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: implications for interdisciplinary action research. NJAS − Wageningen Journal of Life Sciences, 52: 331-348

Ahn, P.M., 1993. Tropical soils and fertiliser use. Longman, Harlow.

Amanor, K.S., 1993. Wenchi Farmer Training Project: Social/environmental baseline study: Unpublished report to Overseas Development Administration, Accra, Ghana.

Asiamah, R.D., Adjei-Gyapong, T., Yeboah, E., Fening, J.E., Ampontua, E.O. and Gaisie, E., 2000. Report on soil characterisation and evaluation at four Primary Cassava Multiplication Sites (Mampong, Wenchi, Asuansi and Kpeve) in Ghana. Technical Report No. 200, Soil Research Institute, Kumasi.

Asuming Brempong, S., Al-Hassan, R., Sarpong, D.B., Kwadzo, G.T.M., Akoena, S.K.K., Sakyi-Dawson, O., Mensah-Bonsu, A., Amegashie, D.P.K., Egyir, I. and Ashley, S., 2004. Poverty and Social Impact Analysis (PSIA) Studies in Ghana: Economic Transformation of the Agricultural Sector. Final report submitted to National Planning Development Commission, Ministry of Food and Agriculture and DFID, Accra, Ghana.

Batiano, A., Lompo, F. and Koala, S., 1998. Research on Nutrient flows and balances in West Africa: State of the art. Agriculture, Ecosystem and Environment, 71: 19-35.

Berry, S., 1993. No condition is permanent – the sociological dynamics of agrarian change in sub-Saharan Africa. The University of Wisconsin Press, Madison.

Collinson, M. P. (ed.), 2000. A history of Farming Systems Research. CABI Publishing, Wallingford, UK.

Devereux, S., 2001. Livelihood Insecurity and Social Protection: A Re-emerging issue in Rural Development. Development Policy Review, 19: 507-509.

Dharmawan, A.H., 2001. Farm household livelihood strategies and socio-economic changes in rural Indonesia. Sozialokonomische-Schriften-Zur-Ruralen-Entwicklung, 124: 244-263.

Edja H., 2001. *Land* Rights under Pressure: Access to Resources in Southern Benin. International Institute for Environment and Development, London.

Elias, N. and Scotson J.L., 1965. The established and the outsiders. Frank Cass & Co Ltd., London.

Elmhirst, R.J., 1996. Soil fertility management in the context of livelihood systems among transmigrants in the north Lampung. Agrivita, 19: 212-220.

Fischer, R. and Ury W., 1981. Getting to yes: Negotiating agreement without giving in. Penguin Books Ltd., Harmondsworth.

Gladwin, C.H., Thomson, A.H., Peterson, J.S. and Anderson, A.S., 2001. Addressing food security in Africa via multiple livelihood strategies of women farmers. Food Policy, 26: 177-207.

Grandin, B.E., 1988. Wealth Ranking in Smallholder Communities: A field manual. Intermediate Technology Publications Ltd, London.

Hart, R., 2000. Farming Systems Research’s Expanding Conceptual Framework. In M.P. Collinson (ed.) A history of Farming Systems Research. CABI Publishing, Wallingford, UK.

Jones, J.H.M. and Sakyi-Dawson, O., 2001. Linking formal and informal financial intermediaries in Ghana: a way to increase women’s access to financial services? In B. Lemire, R. Pearson and G. Camphell (eds) Women and Credit, Researching the Past, Refiguring the Future. Oxford University Press, London.

Leach, M. and Fairhead, J. (2000) Challenging Neo-Malthusian Deforestation Analyses in West Africa’s dynamic Forest Landscapes. Population and Development Review, 26: 17-43.

Leeuwis, C., 1993. Of computers, myths and modelling: The social construction of diversity, knowledge, information and communication technologies in Dutch horticulture and agricultural extension. Wageningen Studies in Sociology, Nr. 36. Wageningen Agricultural University, Wageningen.

Leeuwis, C. and Van Den Ban, A., 2004. Communication for Rural Innovation: Rethinking Agricultural Extension (3rd edition). Blackwell Science, Oxford.

Long, N., 1990. From paradigm lost to paradigm regained? The case for an actor-oriented sociology of development. European Review of Latin American and Caribbean Studies, 49: 3-32.

Mastenbroek, W.F.G., 1997. Onderhandelen. Uitgeverij het Spectrum B.V., Utrecht.

Mettrick, H., 1993. Development Oriented Research in Agriculture: An ICRA Textbook. ICRA, Wageningen.

Mosse, D., Grupta, S., Mehta, M., Shah, V.and Rees, J., 2002. Brokered livelihoods; debt, labour migration and development in tribal western India. Journal of Development, Studies 28: 59-88.

Offei, S.K and Sakyi-Dawson, O., 2002. Technographic studies on cowpea as a private sector crop in Ghana. Online document at URL http://www.dpw.wageningen-ur.nl/forum. Accessed 12 September, 2002.

Ondiege, O., 1996. Land tenure and soil conservation. In C. Juma and J.B. Ojwang (Eds) In Land We Trust, Environment, Private Property and Constitutional Changes. Initiative Publishers, Nairobi.

Robotham, M.P. and McArthur, H.J., 2001. Addressing the needs of small-scale farmers in the United States: Suggestions from FSR/E. Journal of Sustainable Agriculture, 19: 47-64.

Tavernier, E.M. and Tolomeo, V., 2004. Farm Typology and Sustainable Agriculture: Does Size Matter? Journal of Sustainable Agriculture, 24: 33-46.

Tittonell, P., Vanlauwe, B., Leffelaar, P.A., Rowe, E.C and Giller, K.E., 2005. Exploring diversity in soil fertility management of small-holder farms in Western Kenya. I. Heterogeneity at region and farm scale. Agriculture, Ecosystem and Environment, 110: 149-165.

Vanclay, F., Mesiti, L. and Howden, P., 1998. Styles of Farming and Farming Subcultures: Appropriate concepts for Australian rural sociology? Rural Society, 8: 85-107.

Van der Ploeg, J.D., 1994. Styles of farming: an introductory note on concepts and methodology. In: J.D. Van der Ploeg & A. Long (Eds) Born from within: practices and perspectives of endogenous development, Assen: Van Gorcum.

CHAPTER 4

Productivity, yield and N_2-fixation in cowpea varieties and their subsequent residual N effects on a succeeding maize crop: farmers' agronomic and social indicators

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Abstract

Cowpea-maize rotations form an important component of the farming systems of the smallholder farmers in the forest/savannah transitional agro-ecological zone of Ghana. We evaluated five cowpea varieties for grain yield, N_2-fixation, biomass production and contribution to productivity of subsequent maize crop grown in rotation. We further analysed the interrelationship between these technical dimensions and the social acceptability of these cowpea varieties for farmers. Cowpea grain yield ranged between 1.07 to 1.31 t ha^{-1} on researcher-managed fields and 1.11 to 1.39 t ha^{-1} on farmer-managed fields with no significant differences in yield among the different varieties. Using the ^{15}N natural abundance technique to estimate N_2-fixation, the proportion of N_2 fixed ranged 46-68, 60-77, 63-78, 64-79 and 68-81 % for the cowpea varieties Ayiyi, IT810D-1010, Asontem, Adom and Legon prolific. This resulted in average amounts of N_2 fixed of 32, 34, 43, 41 and 67 kg N ha^{-1} respectively. The amount of soil derived N ranged from 15-20 kg N ha^{-1}. The net N contribution of the cowpea varieties to the soil (after adjusting for N export in grains) was highest for Legon prolific (31 kg N ha^{-1}) due to high N_2-fixation and high leaf biomass production. Maize grain yield after cowpea without application of mineral N fertiliser ranged between 0.76 t ha^{-1} with Asontem to 1.46 t ha^{-1} with Legon prolific on researcher-managed fields compared with 0.38 t ha^{-1} after maize, and 0.83 t ha^{-1} with IT-810D-1010 to 1.66 t ha^{-1} with Legon prolific compared with 0.25 t ha^{-1} after maize on farmer-managed fields. The N fertiliser equivalence values for the cowpea varieties ranged between 18 to 60 kg N ha^{-1}. Cowpea variety IT810D-1010 was ranked by the farmers as the most preferred cowpea variety due to its white seed type, short-duration, ease of harvesting and good market value, which was confirmed by simple economic analysis. Despite of the high leaf biomass production and high amount of N_2 fixed by Legon prolific, it was the least preferred variety by the farmers due to lower market price, late maturity, least potential cash income (due to the red mottled seed type) and difficulty in harvesting. Although farmers recognized the contribution of cowpea to soil fertility and yields of the subsequent maize crop, they did not consider this as an important criterion when selecting varieties for use in their own fields. Our results suggest that soil fertility improvement must be considered as an additional benefit

rather than a direct selection criterion when designing more sustainable smallholder farming systems.

4.1. Introduction

The potential of the forest/savannah transitional agro-ecological zone of Ghana for the production of food crops is limited by poor soil fertility, and in particular, deficiencies of nitrogen (N) and phosphorus (P) (Nye and Stephens, 1962). Although mineral fertilisers can improve crop nutrition, they are sparingly used by farmers in this part of Ghana, as in many regions in sub-Saharan Africa, partly due to the prohibitive cost as a result of removal of government subsidies (Gerner *et al.*, 1995). Preliminary field experiments in Wenchi revealed N to be the most limiting nutrient (unpublished results), supporting farmers' observations that grain legumes, particularly pigeonpea and cowpea, play an important role in maintaining and improving soil fertility.

While cowpea is grown by most farmers due to its short growing cycle, rotations with pigeonpea are common among the native farmers who own land (Adjei-Nsiah *et al.*, 2004). Migrants cannot own land in these communities but can access land for farming either through share cropping or renting. Migrants rent land only for short periods and land owners demand advance payment of rents. Rotations with long duration crops such as pigeonpea are therefore not the options preferred by landless farmers like migrants. Short rotations with cowpea appear to be more attractive for migrant farmers because of the shorter cycle and because the grain can be used both for food and for sale, in addition to the role of cowpea in improving N availability for subsequent crops. In Wenchi, cowpea appears to be a crop that is grown mainly by male farmers. While female migrants do not farm independently, native females often lack the resources required for ploughing the land and spraying the crop against insect pests (see Adjei-Nsiah et al., 2006).

Cowpea can fix more than 50% of its N from N_2-fixation (Ofori *et al.*, 1987; Awonaike *et al.*, 1990). In Ghana, Dakora et al. (1987) estimated that cowpea can contribute up to 201 kg N ha^{-1} through N_2-fixation. However, the net N-contribution of cowpea cultivars varies with the amount of N_2 fixed and the proportion of the plant N that is harvested (Eaglesham *et al.*, 1982). Above-ground residues of cowpea contribute a substantial amount of N to the following crop in rotation, as well as the smaller amounts returned to the soil in decaying roots and nodules (Dakora *et al.*, 1987; Sisworo *et al.*, 1990). Thus cultivars that combine a reasonable grain yield with a large volume of leaf biomass could offer a useful compromise to meeting farmers' food security concerns and improving soil fertility (Giller and Cadisch, 1995).

Traditionally, in the forest/savannah transitional agro-ecological zone of Ghana with two growing seasons, farmers grow cowpea in the major growing season between April and July and follow it with maize during the minor growing season between September and January. Although it is usually assumed that cowpea varieties preceding maize provide substantial amounts of N to the maize crop through N_2-fixation, the acceptability of different cowpea varieties to maize farmers in the forest/savannah transitional agro-ecological zone and the reasons on which they select their choice of varieties is not fully understood. Moreover, most studies on N_2-fixation carried out on research stations where adequate water and nutrients other than N are provided may bear very little relation to the situation in farmers' fields, where growing conditions may be sub-optimal (Giller, 2001).

The yield of five cowpea varieties developed by the National Agricultural Research System (NARS) in Ghana and their effects on the yield and N uptake of a subsequent maize crop grown in rotation were assessed in researcher-managed and farmer-managed experiments on farmers' fields. In the researcher-managed experiment, N_2-fixation in the various cowpea varieties was measured using the ^{15}N natural abundance technique, and the net N benefits to the soil and subsequent maize crop were calculated. We also analysed farmers' preferences and criteria for selecting from the different varieties of cowpea for use in their crop rotations.

4.2. Materials and Methods

4.2.1. Study area

A trial to compare production and N_2-fixation in various cowpea varieties, and their effects on yield and N uptake of a subsequent maize crop was conducted in three neighbouring communities namely Asuoano (7^{o}41′ N, 2^{o}05′ W), Beposo (7^{o}42′ N, 2^{o}05′ W) and Droboso (7^{o}43′ 2^{o}05′ W) in Wenchi district of Brong Ahafo region of Ghana in both researcher-managed and farmer-managed experiments. Wenchi, which is typical of the forest/savannah transition, was originally semi-deciduous forest that has been converted to savannah woodland through intensive cultivation. The soils are Lixisols which developed over Voltaian sandstone (Asiamah *et al.*, 2000). The chemical and physical properties of the surface soil of the experimental plots are presented in Table 1. The site has a bimodal rainfall pattern with a 30-year annual mean of 1271 mm with 127 rainy days. Total rainfall during the 1 year trial period was 1350 mm. The study area was selected as representative of this region after an initial exploratory study (Offei and Sakyi-Dawson, 2002). Fields were selected for the experiments by local farmers specifically to represent soil conditions where repeated cropping had led to depletion in nutrient availability and poor soil fertility for crop production.

Table 1. Chemical and physical soil properties of surface soil (0-20 cm) of experimental plots before the planting of cowpea in 2003.

Experiment	pH (H_20)	Organic C (%)	Total N (%)	Bray-1 P (mg kg^{-1})	Sand	Silt (%)	Clay
Researcher-managed plots							
	6.1	0.58	0.06	4.3	84	3	13
Farmer-managed plots							
Asuoano	5.9	0.63	0.08	6.8	79	4	17
Beposo	5.8	1.15	0.08	5.2	66	12	22
Droboso	5.2	0.45	0.07	6.4	84	5	11

4.2.2. Researcher-managed experiment

The land where the experiment was situated had been left fallow for two years and was dominated by *Imperata cylindrica* (speargrass); yam had been grown in this field earlier. The grass was cleared by slashing with a cutlass and removing the standing biomass. Four weeks later the land was ploughed and harrowed. After a further four weeks, herbicide (glyphosate) was applied at the rate of 900 g a.i. ha^{-1}. Five cowpea varieties namely Ayiyi, Asontem, Adom, IT810D-1010 and Legon prolific and local maize (var. Dorke SR) were planted eight days later at the end of May, 2003. The six treatments were randomised within four replicate blocks. Four of the cowpea varieties compared in this experiment (Ayiyi, Asontem, Adom and IT810D-1010) were selected by farmers from ten varieties which had been sown in a participatory varietal selection trial. Legon prolific, a dual-purpose variety was not initially selected by the farmers because of its late maturity period, but we decided to include it in the experiment because it produced much more biomass than the other varieties. The plot size was 12 m x 12 m with 2 m paths between the plots. Cowpea rows were spaced at 60 cm and two seeds per hill were sown at 20 cm intervals within the rows. Maize (var. Dorke SR) was planted at 80 cm x 40 cm with two seeds per hill.

Plots were weeded by hand four weeks after planting. Insecticide (containing cypermethrin and dimethoate) was applied at four weeks after planting and at flowering to control insect pests. An area of 1.8 m^2 was harvested at late pod filling from all plots for N_2-fixation measurements. Maize from the plots and some non-legume reference plants (*Croton lobatus, Eclipta alba, Imperata cylindrica* and *Celosia trigyna*) growing around the plot borders were sampled and used as reference plants for estimating N_2-fixation using the $\delta^{15}N$ technique (Peoples *et al.*, 1989).

An area of 10.8 m^2 (3 rows of 6 m) was harvested when the crops were mature. The vines and pods were separated and the pods were dried and shelled. The fallen leaf litter was collected from the harvest area of cowpea. Maize was harvested 96 days after planting: plants were counted; stover, cobs and grain were separated and weighed. Sub-samples of all harvested samples were taken and oven-dried at 70 ^oC for 2 days to determine dry matter contents.

In August 2003 after the cowpeas and the first season maize were harvested, the stover comprising the litter and vines were ploughed into the soil by hand using a hoe. The maize stalks were cut into 20 cm pieces and incorporated into the soil. A maize variety, Dorke SR was planted on all the plots at a distance of 80 cm x 20 cm with 3 seeds per hole. The maize pockets without germination were replanted 10 days after the first planting. The stand was thinned to one plant per hill 2 weeks after planting. All plots were split into 5 sub-plots, which received 0, 30, 60, 90 and 120 kg N ha^{-1} as ammonium sulphate in two split applications: half 14 days and half 42 days after planting. Weeding was done at 4 weeks after planting.

At maturity, maize ears and stalks were harvested from the two central rows of each sub-plot, leaving a 1 m border at both ends, and weighed. A sub-sample of 10 cobs per plot was taken and grain removed and weighed.

Sampling handling and analysis

Cowpea was separated into pods and shoots and maize into cobs and shoots; sub-samples (500 g) were oven-dried at 70 ^{o}C for 48 h to determine dry matter contents. All grain yield data are presented with a correction for 12% moisture content. After weighing, all plant samples were ground to pass to 1 mm and sub-samples taken for N analysis. Samples from cowpea and reference plants were analysed for % N and $\delta\ ^{15}N$ using a 20-20 stable isotope mass spectrometer, coupled to a CN auto-analyzer. %N in maize samples from the second season was determined by Kjeldahl digestion and colorimetric analysis of NH_4-N in the digests.

Calculations

The %N derived from N_2-fixation was calculated from the $\delta^{15}N$ values as:

$$\%N \text{ from } N_2\text{-fixation} = \{[\delta^{15}N_{\text{reference plant}} - \delta^{15}N_{\text{legume}}]/ [\delta^{15}N_{\text{reference plant}} - B]\}\ 100$$

where B is a measure of isotopic fractionation during N_2-fixation and the reference plant is a non-N_2-fixing plant. The B value used for cowpea in this experiment was -1.51‰ (Nguluu *et al.*, 2002). The amount of N_2-fixed was calculated from the total N accumulated by the cowpea varieties. The amount of N_2-fixed was also estimated by the N difference method as:

$$N \text{ from } N_2\text{-fixation} = N_{\text{legume}} - N_{\text{maize}}$$

and the %N derived from N_2-fixation calculated as:

$$\%N \text{ from } N_2\text{-fixation} = (N_{\text{legume}} - N_{\text{maize}} / N_{\text{legume}}) \times 100$$

to provide a second, independent estimate of the %N from N_2-fixation.

The net contribution of N_2-fixation to the overall N balance was calculated as:

Net N-balance = Nb - Ng

where Nb = proportion of N from fixation (as assessed from the $\delta^{15}N$ values) x total biomass N and Ng = grain N exported (modified from Peoples and Craswell, 1992).

4.2.3. Farmer-managed experiment

Collaborative farmer groups in each of the communities were made up of migrant and native farmers. We included both migrants and natives in the study because a previous study (Adjei-Nsiah *et al.*, 2004) indicated that migrants and natives use different soil fertility management practices due to differential land tenure arrangements. For instance, due to tenure insecurity and unfavourable land tenure arrangements, migrants use short-term practices such as mounding or ridging and rotation with short duration crops such as cowpea for managing the fertility of their soils. On the other hand the land-owning native farmers rely on rotations with crops like pigeonpea, cassava and cowpea in managing the fertility of their soils. Selection of farmers was based on interest and preparedness to spend one day each week on the experimental field. The composition of farmers in the various groups was as follows: Asuoano (9 natives, 8 migrants); Beposo (6 natives, 6 migrants) and Droboso (8 natives and 7 migrants). Migrant farmers were all males, while native participants were of mixed gender. The experiment was conducted on collective plots in each of the three communities, as suggested by the farmers.

Land preparation on farmers' fields consisted of ploughing by tractor followed by harrowing using hoes. Planting, field management and harvesting decisions were made by farmers. All participating farmers in each of the communities met with the researcher and decided when to plant, spray with insecticide and harvest. Under normal farmers' practice cowpeas are sprayed when insects are observed on the plants. However in this experiment the cowpeas were sprayed only when insect damage was observed, therefore the fields were sprayed only twice instead of normal farmers' practice of three or more sprays before harvest. Each experiment comprised one complete block of treatments, giving three replicate blocks.

Litter traps measuring 50 cm by 50 cm were placed under the canopies of the cowpea to trap litter falling from the cowpea varieties. The litter was examined together with the farmers to illustrate the amount of litter produced by each of the varieties and returned to the soil. At 50% flowering five plants each were removed from each of the plots to study the nodulation potential in each of the cowpea varieties. In each of the three communities farmers assessed the performance of the cowpea varieties through ranking and scoring at harvest. Each variety was compared directly against the others until they were ranked from the variety the farmers liked best to what they considered the least useful. After the cowpeas were harvested, the cowpea biomass was incorporated into the soil using hoes. Some farmers collected various cowpea varieties of their choice and planted them on their individual fields during the next season which was the minor rainy season. After harvesting the cowpea varieties on their individual plots, the farmers were asked to score and rank the varieties again to see if their preferences would change. In August 2003, a local maize variety (var. Dorke SR) was planted on all the cowpea plots to assess the beneficial effects of the cowpea varieties on the subsequent maize yield. The beneficial effect of the cowpea on maize grain yield was assessed with the farmers through ranking and scoring, as well as by harvesting and weighing the grain produced. All grain yield data are presented with a correction for 12% moisture content.

4.2.4. Economic analysis

Costs of production were divided into inputs and labour costs. Costs of inputs were determined using prices of local planting materials and plant protection chemicals. Labour costs for the field operations (land preparation, planting, weeding, collecting water and spraying, harvesting and threshing) were determined together with the collaborative farmers based on existing labour rates in the communities. All amounts of money are expressed in US dollars at the average exchange rate between December, 2003 to June, 2005: ¢9000 to US$1 (Bank of Ghana, 2005). Prices for cowpea and maize were based on the average of the national average wholesale price between 2002 and 2004 (ISSER, 2005). The cowpea price was however adjusted to reflect the relative prices for the different varieties in the local market using the average for the 2000-2004 prices as the minimum.

A simple financial analysis was performed to evaluate the profitability of each of the cowpea varieties and the maize crop. The analysis included total revenue and cost of production per hectare for each of the cowpea varieties and the maize crop during the first season and that of the succeeding maize crop in the second season when no N fertiliser was applied to the maize. From these, the net revenues for each crop as well as the full rotation were determined. The net revenue from the investment was given by:

NR=TR-TC

Where NR is the net revenue; TR, total revenue; and TC is total cost.

Returns on investment (RI) were also computed thus:

RI = NR/TC

Where an RI > interest rate on capital implies profitability.

5.2.5. Statistical analyses

Data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure (SAS, 1996).

4.3. Results

4.3.1. Grain and stover yield, N accumulation and N_2-fixation in cowpeas

Grain yield of the five cowpea varieties ranged from 1.07 to 1.31 t ha^{-1} in the researcher-managed field and 1.11 to 1.39 t ha^{-1} in the farmer-managed fields (Table 2) with no significant difference in yield between varieties. While there were no significant differences in grain N between the varieties, which ranged from 26 to 36 kg N ha^{-1}, N in stover ranged from 23 kg N ha^{-1} in IT810D-1010 to 50 kg N ha^{-1} in Legon Prolific. Observations of excavated root systems confirmed that all cowpea plants were well-nodulated in all cases (data not shown). All of the five cowpea varieties had similar $\delta^{15}N$ suggesting that they were fixing similar proportions of their N (Table 2). The $\delta^{15}N$ abundance of shoot and seed samples from each replicate plot were consistent for each replicate plot as indicated by the linear relationship between $\delta^{15}N$ of seed and shoot samples (Figure 1). Using the natural abundance technique, estimates of the %N from N_2-fixation ranged from 46-68% in Ayiyi to 68-81% in Legon Prolific depending on the reference plant used. In this experiment, the estimates obtained were more dependent on differences in $\delta^{15}N$ among reference plants (Table 3). The dicotyledonous non-fixing reference plants had higher $\delta^{15}N$ abundance than the monocotyledonous reference plants and indicated more N was fixed in all cowpea

Table 2. Yield, nitrogen contents and δ ^{15}N values of grain and stover of five cowpea varieties grown in Wenchi, Ghana.

Variety	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Grain N (kg ha^{-1})	Stover N (kg ha^{-1})	Grain δ^{15}N (‰)	Stover δ ^{15}N (‰)
Researcher-managed experiment						
Adom	1.14	1.31	30	26	0.22	0.29
Asontem	1.08	1.23	35	24	0.32	0.33
Ayiyi	1.07	1.18	26	26	1.01	1.34
IT810D-1010	1.09	1.22	26	23	0.64	0.21
Legon prolific	1.31	2.59	36	50	0.32	-0.21
SED	0.148	0.214	6	5	0.54	0.55
Pr > F	NS	0.01	NS	0.001	NS	NS
Farmer-managed experiment						
Adom	1.39					
Asontem	1.23					
Ayiyi	1.11					
IT 810D-1010	1.16					
Legon prolific	1.14					
SED	0.246					
Pr > F	NS					

varieties. The N difference method estimates of N_2-fixation indicated significant differences in the %N derived from N_2-fixation among the five varieties, ranging from 35% in IT-810D-1010 to 63% in Legon prolific (Table 3). The %N from N_2-fixation values obtained with this method were consistently smaller than those obtained with the natural abundance method for all the cowpea varieties.

4.3.2. The contribution of N by the different cowpea varieties to the overall soil N economy

The total amount of N accumulated by the varieties ranged from 49 kg N ha^{-1} in IT810D-1010 to 86 kg N ha^{-1} in Legon Prolific (Table 4), and the amount of N_2 fixed in the above ground biomass was 32, 34, 41, 43 and 67 kg ha^{-1} for Ayiyi, IT810D-1010, Adom, Asontem and Legon prolific respectively with significant differences ($P<0.01$) among the varieties (Table 4). While the amount of fixed N in the above-ground biomass of the different cowpea varieties ranged widely, the amount of N accumulated from soil was similar (15-20 kg N ha^{-1}) for all varieties (Table 4). The small amount of total fixed N observed with the white seed varieties Ayiyi and IT810D-1010 (32-34 kg N ha^{-1}) was mainly due to poor biomass production, although they also had a slightly smaller % N from N_2-fixation.

Calculations of the net N balance after accounting for N_2-fixation and removal of N in the grain indicated that all of the cowpea varieties tested were contributing N to the system (Table 4). The largest net N contribution, assuming that all the above ground foliage biomass is retained and incorporated into the soil, was made by Legon prolific (31 kg N ha^{-1}) which yielded the most biomass. The net N contribution from the erect varieties (Adom, Asontem, Ayiyi and IT810D-1010) was relatively small (8-11 kg N ha^{-1}). Assuming 30% of the total plant N is contained in the roots; then the roots can potentially recycle between 21-37 kg N ha^{-1} into the soil. Allowing for this root contribution leads to a total net N balance in the soil of between 19-60 kg N ha^{-1} for the cowpea varieties.

4.3.3. Response of maize succeeding different cowpea varieties

On the farmer-managed plots where no mineral fertiliser application was made, maize grain yields were 0.25, 0.83, 1.10, 1.32, 1.54 and 1.66 t ha^{-1} for plots previously cropped to maize, IT810D-1010, Adom, Asontem, Ayiyi and Legon prolific respectively. Maize grain yield without mineral fertiliser application ranged from 0.38 t ha^{-1} with maize after maize to 1.46 t ha^{-1} with maize after Legon prolific on the researcher-managed plots (Figure 2a). Application

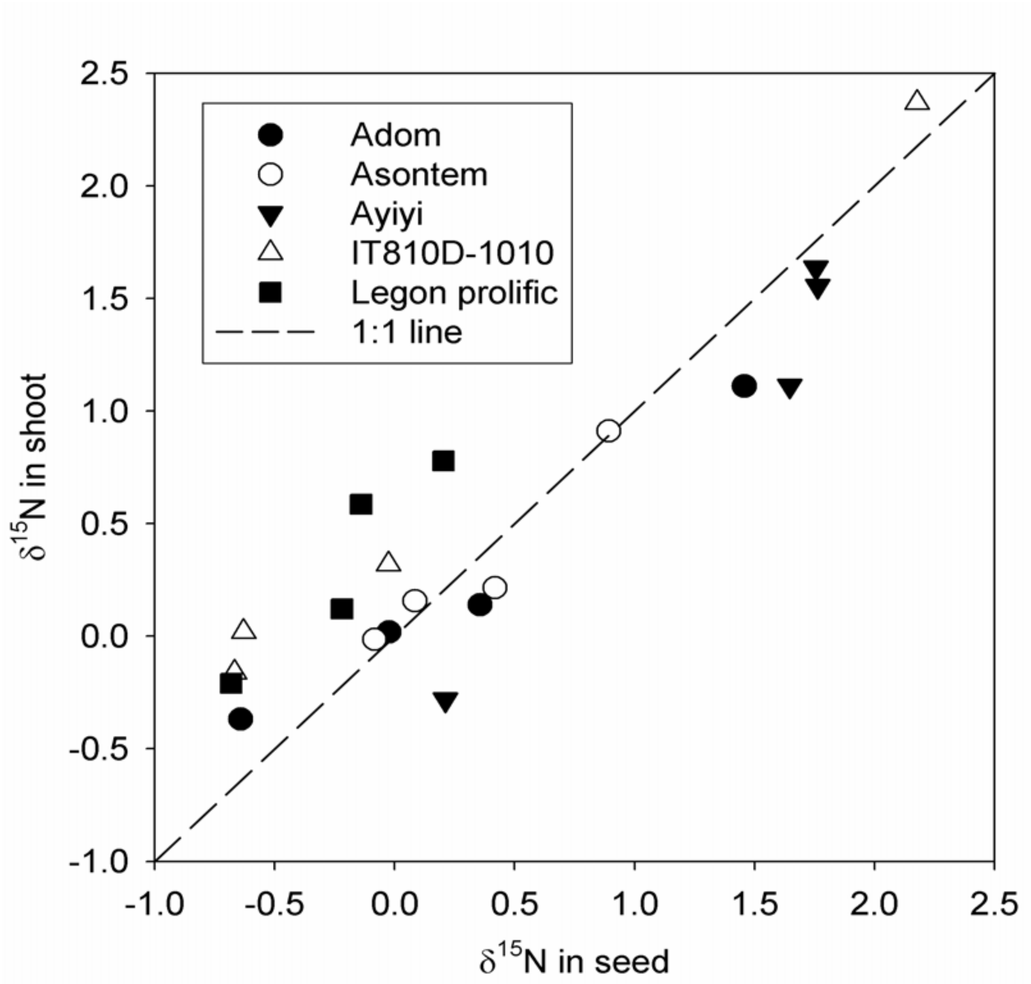

Figure 1 Relationship between δ 15N of cowpea shoot and δ 15N of cowpea seeds for cowpea varieties Adom, Asontem, Ayiyi, IT810D-1010 and Legon Prolific. The dashed line indicates the 1:1 relationship.

of N fertiliser to maize following cowpea further increased maize grain yield except in the case of maize after Legon prolific which did not respond further to N fertiliser. Application of rates of mineral N fertiliser above 30 kg N ha^{-1} to maize following cowpea resulted in no further maize grain yield, whereas 60 kg N ha^{-1} mineral fertiliser were required to achieve similar yields (± 1.25 t ha^{-1}) when maize was grown after maize (Figure 2a).

N-fertiliser equivalence of the cowpea residues were derived by comparing the maize N uptake after the cowpea varieties with no fertiliser applied with the linear N fertiliser response of maize between 0 and 60 kg N ha^{-1} (Figure 2b). This gave an N fertiliser equivalence of 18, 20, 23, 25 and 60 kg N ha^{-1} for Adom, Asontem, IT810D-1010, Ayiyi, and Legon prolific respectively. The relationship between maize grain yield and maize N uptake (internal use efficiency) was similar across all previous cowpea cropping and N fertiliser treatments – indicating a value of 27 kg of grain for each extra kg N taken up by maize (Figure 2c).

4.3.4. Farmers' preferences and perceptions of cowpea varieties

Native and migrant farmers in each of the three villages had slightly different preferences for the different varieties (Table 5a). The shorter duration varieties were preferred by all farmers at Asuano and Beposo, and Legon prolific was the variety they liked least. The variety of first choice varied, although IT810D-1010, Asontem and Adom were generally preferred to Ayiyi. By contrast, Legon prolific was ranked as the most preferred variety by migrant farmers at Droboso, and as second-best variety by the native farmers from this village. The farmers at Beposo cited early maturity, sweet taste, and high market value as reasons for ranking IT810D-1010 as the most preferred variety. After the farmers had grown the varieties themselves, the ranking of varieties did not change markedly, apart from IT810D-1010 rising in the rank order for the native farmers at Droboso. The preference of this group of farmers for Legon prolific changed markedly, from rank 2 in the group selection to being the least preferred variety. In order to gain better understanding of farmers' preferences, the farmers were asked to discuss and list criteria that they used in their evaluation of the varieties. The criteria used by farmers to rank the varieties were similar among natives and migrants, with market value, short time to maturity and yield being the most important criteria (Table 5b,c).

The varieties selected by farmers for testing in their own fields (Table 5c) tended to support the results obtained by the group and individual preferences (Table 5a). Asontem, IT810D-1010 and Adom were selected by many farmers (24-48%) for testing, whereas Ayiyi was selected by few farmers (10%). Legon prolific was selected only by 3 farmers (from Droboso) who use this variety as a leafy vegetable.

4.3.6. Economic analysis

In the first season, all the five cowpea varieties gave net revenues ranging from about US$143-396 ha^{-1} while the maize crop gave negative net revenue of US$26 ha^{-1} (Table 6a). These represent returns on investment ranging from 66 to 181% for the cowpea varieties and –19% for maize. Among the cowpea varieties, the highest return on investment was made with IT-810D-1010, while the least return was made with Ayiyi.

4.4. Discussion

4.4.1. Grain and biomass yields and N_2-fixation of the cowpea varieties

Cowpea grain yields were similar in the researcher-managed experiment conducted on a farmers' field, and in the farmer experiments, ranging from 1.07 to 1.39 t ha^{-1} (Table 2). There were no significant differences in grain yield between the different cowpea varieties, despite the large differences in growth habit and duration between the determinate, erect varieties, (Asontem, Adom, Ayiyi and IT810D-1010) which matured in 65-70 days and the indeterminate, creeping variety (Legon prolific) which matured only after 90 days. By contrast, twice the amount of stover (2.59 t ha^{-1}) was harvested from Legon prolific, as from the erect varieties (1.18-1.31 t ha^{-1}). These differences were reflected in the amounts of N accumulated: there were no significant differences between N accumulation in grain between the cowpea varieties (range from 26 to 36 kg N ha^{-1}) but large differences in stover N which ranged from 50 kg N ha^{-1} in Legon prolific to 24-26 kg N ha^{-1} in the erect varieties (Table 2).

4.4.2. Measurements of N_2-fixation

The $\delta^{15}N$ enrichments of the different reference plants varied from 3.38‰ in *Imperata* to 6.78‰ in *Celosia* (Table 3). There were no significant differences in $\delta^{15}N$ values between the cowpea varieties (although Ayiyi generally had higher enrichments; Figure 1), but the variation in reference values gave a fairly wide range of estimates of the %N from N_2-fixation (Table 3). The N_2-fixation estimates obtained using the natural abundance method with the reference plants with lower enrichments gave closer agreement to the estimates obtained using the N difference method, but there is no objective basis on which to choose among the reference plants. The variation in the $\delta^{15}N$ values observed among the different reference plants might be due to differences in rooting depths and patterns and isotopic discrimination during N assimilation (Unkovich and Pate, 2000), although such processes are poorly understood. The amounts of N_2-fixed calculated using the ^{15}N-natural abundance method varied from 32 to 41 kg N ha^{-1} in the erect cowpea varieties to 67 kg N ha^{-1} in the creeping variety Legon prolific (Table 4), but the amounts of soil N differed little between the varieties (range of 15-20 kg N ha^{-1}).

The absence of significant differences in soil N uptake among the different cowpea varieties suggests they had equal access to the same soil N pool and that there were no significant differences in their rooting depths. The N difference method of estimate depends on the assumption that both the N_2 fixing plant and the reference plant take up the same amount of soil N, an assumption that is unlikely to be satisfied (Unkovich and Pate, 2000). The N difference method gave consistently smaller estimates of the %N from N_2-fixation for all of the cowpea genotypes, presumably because the maize crop was able to take up more N from the soil (32 kg N ha^{-1}) than the cowpea varieties (Table 3).

In Cote d'Ivoire, using the natural abundance method, Becker and Johnson (1998) reported that cowpea fixed between 38 and 86% of its N within 180 days. Using the ^{15}N-isotope dilution method, cowpea fixed between 52 and 70% of its N (Awonaike *et al.*, 1990). Ofori *et al.* (1987) in contrast reported a narrower range of values (69-74%) for cowpea, similar to the values found in our experiments on farmers' fields (Table 3).

4.4.3. N recycling and residual effects of cowpea varieties on maize yield and N uptake

The differences in amounts of N recycled and the net N contributions to the soil reflected the amounts of N in the stover as the amount removed in grain was fairly constant among the varieties (Table 4). The net N contribution after Legon prolific (31 kg N ha^{-1}) was much greater than that from the erect cowpea varieties (6-11 kg N ha^{-1}) when only above-ground plant growth was considered. The relative differences between the varieties were smaller when the net N contribution was recalculated allowing for a 30% below-ground N contribution from the roots and nodules, although the estimated inputs from Legon prolific (60 kg N ha^{-1}) were still double that from the other varieties (19-28 kg N ha^{-1}; Table 4). All of the maize yields after the erect cowpea varieties (0.82-1.00 t ha^{-1}) were better than the maize yield after maize (0.38 t ha^{-1}), but the yield after Legon prolific was much greater (1.46 t ha^{-1}; Figure 2). Similar results were found in both the researcher-managed and farmer-managed experiments. These residual effects on maize yields were proportional to the amounts of N recycled and the net N contributions (cf. Table 4), and equivalent to 20-25 kg N ha^{-1} with the erect cowpea varieties and 60 kg N ha^{-1} with Legon prolific (Figure 2). Given that it is unlikely that the N returned in cowpea biomass is equally available as mineral fertiliser, it seems likely that the estimates of N recycled including a contribution from the roots (Table 4) are more realistic. The maize variety used is a local variety not particularly N responsive compared with hybrid varieties. Maize yields were further increased with N fertiliser, except after Legon prolific indicating that supplementary N fertiliser is required to maximize maize yields when preceded by short-duration, erect cowpea varieties.

In similar studies in West Africa N fertiliser equivalence values of 10-72 kg N ha^{-1} have been estimated for cowpea (Dakora *et al.*, 1987; Carsky *et al.,* 1999); a similar range to that found in our experiments. Although the rotation effects of cowpea appear to be attributable largely to the cowpea contribution of N, other non-N benefits may have played a role such as breaking of cereal pest and disease cycles (Francis and Clegg, 1990), enhanced mycorrhizal colonisation (Harinikumar and Bagyaraj, 1988) and improvements in soil structure (Peoples and Craswell, 1992).

4.4.4. Economic analyses and farmers' evaluation of the cowpea varieties

Farmers evaluated the cowpea varieties in terms of marketability, taste, maturity period, labour demand (in terms of harvesting), pod length and seed size (Table 5b). Farmers at Asuoano and Beposo rejected Legon prolific on the grounds that it took the longest time to reach maturity and was difficult to harvest, although they were aware that it might improve soil fertility. However, both the native and migrant farmers from Droboso, ranked Legon prolific highly. Legon prolific is similar to a local variety which is grown by the Dagarbas who are the predominant migrants in Droboso, and they like such varieties due to their biomass as they use the leaves as a vegetable. Legon prolific also produced the highest grain yield in their farmer-managed experiment. Soon after the first ranking most of the farmers collected seeds of some of the varieties and planted them on their own individual plots for further evaluation in a season when pest population was usually high (Table 5c). After planting some of the varieties on their own individual fields after the first ranking, farmers' preferences and evaluation changed to some extent. Most of the farmers who planted IT810D-1010 observed high susceptibility of this variety to insects during the minor growing season and therefore reduced grain yield. Nevertheless, the migrant farmers ranked this variety as their most preferred variety due to its taste, high market value and its early maturity. Farmers at Droboso who initially ranked Legon prolific as a preferred variety changed their preference after planting it in their own individual fields (Table 5a) partly because of its long duration and partly because of its lower market value. Legon prolific takes longer than 90 days to mature when planted in October so that it matures in January which is a dry period and not favourable for grain filling. Further, the Legon prolific has a mottled red seed which is not in high demand as most consumers in the local markets prefer the white seed varieties. In addition, owing to its creeping habit, harvesting of Legon prolific is laborious and requires extra labour for harvesting. The farmers' varietal choice is supoprted by the economic analyses. Cowpea variety IT810D-1010 had by far the largest net revenue (US$396 ha^{-1}) and return on investment (181%) compared with the other varieties (US$143-292 ha^{-1} and 66-132%) (Table 6). During focus group discussions in the field, the farmers noted that yields of maize after cowpea varieties were consistently better than yields after maize. The farmers observed and commented on the greater litter fall from Legon prolific (data not presented). They further stated that stronger effect of Legon prolific in improving the yield of the subsequent maize crop compared with the other cowpea varieties was due to the greater litter fall with this variety. Their comments at this point resembled those made during the initial selection of cowpea varieties for the experiments. At that moment, farmers did not select Legon prolific as an interesting variety to experiment with even if discussions in the group made it clear that they expected this variety to perform well in terms of soil fertility improvement. The economic benefits of Legon prolific due to its residual soil fertility effects on improving the yield of the subsequent maize crop were demonstrated by the simple economic analysis. Maize after Legon prolific gave net revenue of US$126 ha^{-1} and return to investment of 92% compared with net revenues of US$13-54 ha^{-1} and returns to investment

Table 3. Proportion of nitrogen in cowpea varieties derived from N_2-fixation using the ^{15}N natural abundance technique and the nitrogen difference method.

Cowpea Variety	% N derived from N_2-fixation estimated using the ^{15}N natural abundance technique				% N derived from N_2-fixation estimated using the N difference method with maize as a reference plant
	Average for all five reference plants	Average for Dicot reference plants	Average for Monocot reference plants	Range for individual reference plants	
Adom	75	77	71	64-79	40
Asontem	73	76	69	63-78	44
Ayiyi	61	64	56	46-68	38
IT810D-1010	71	74	67	60-77	35
Legon prolific	77	79	74	68-81	63
SED	8	7	9		8
Pr > F	NS	NS	NS		0.05

Means of δ ^{15}N values for reference plants: *Celosia trigyna* = 6.78‰; *Croton lobatus* = 6.26‰; *Eclipta alba* = 4.8‰; *Imperata cylindrica* = 3.38‰; *Zea mays* = 5.49‰

Table 4. N sources and net N contributions (kg N ha^{-1}) to the overall soil N economy of five cowpea varieties when only above ground N is considered or when a correction factor for root N is included assuming that 30% of total N is in the roots.

Variety	Total biomass N	N sources: N_2-fixation	N sources: soil	N in roots	Litter N content	Vine N content	Grain N removed	N recycled	Net N contribution
Only above ground N considered									
Adom	56	41	15	–	12	14	30	26	11
Asontem	59	43	16	–	9	15	35	24	8
Ayiyi	52	32	20	–	10	16	26	26	6
IT810D-1010	49	34	15	–	13	10	26	23	8
Legon prolific	86	67	19	–	30	20	36	50	31
SED	8	7	6	–	3	2.5	6	5	6.5
Pr > F	0.01	0.01	NS	–	0.001	NS	NS	0.001	0.01
Assuming 30% of total plant N is in the roots									
Adom	79	58	21	24	12	14	30	50	28
Asontem	84	61	23	25	9	15	35	49	26
Ayiyi	74	45	29	22	10	16	26	49	19
IT810D-1010	70	49	21	21	13	10	26	44	23
Legon prolific	122	95	27	37	30	20	36	87	60
SED	12	10	8	5	3	2.5	6	8	9
Pr > F	0.01	0.01	NS	0.01	0.001	NS	NS	0.001	0.01

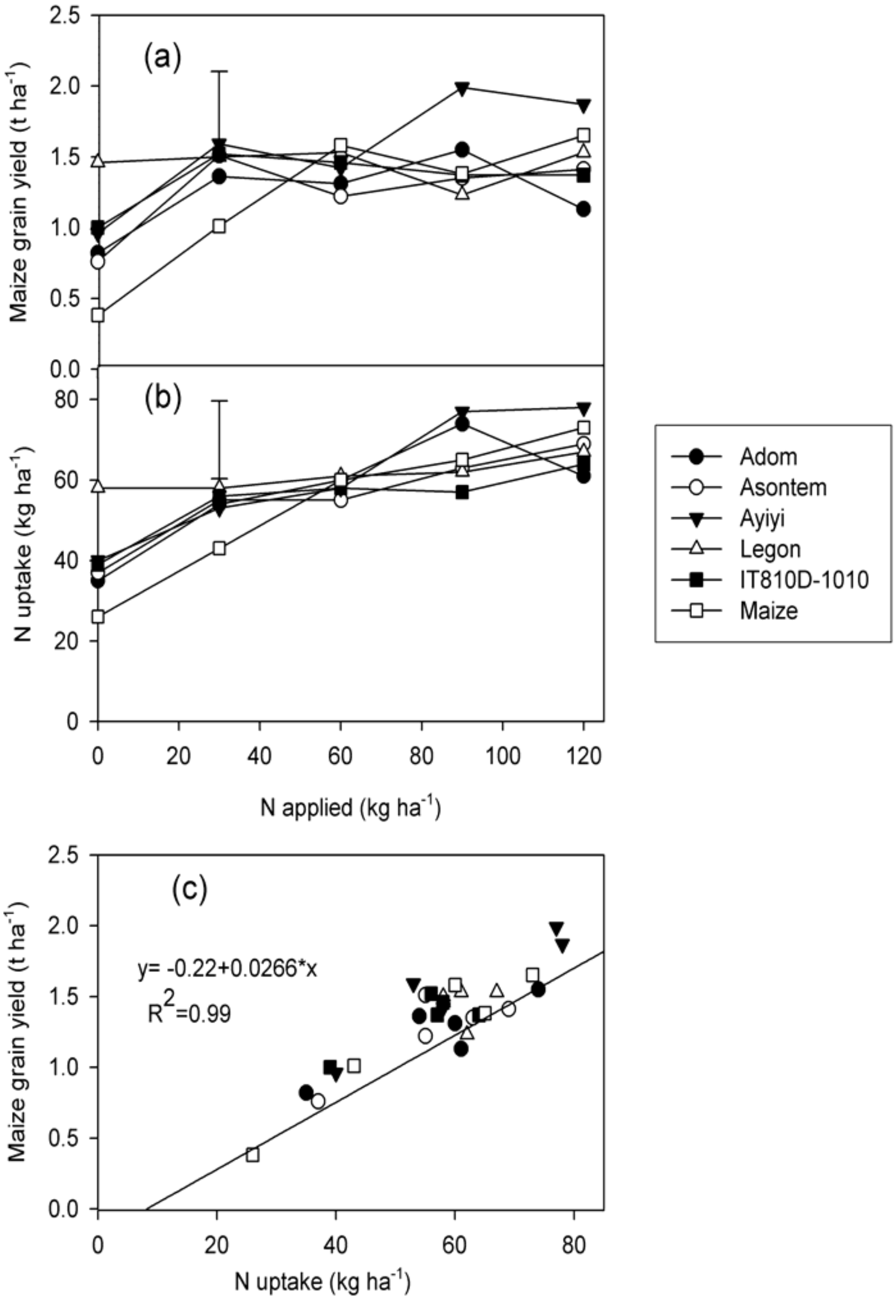

Figure 2. Relationships between a) N applied and maize grain yield b) N applied and N uptake and c) N uptake and maize grain yield. Vertical error bars represent SE.

Table 5. Farmers' selection of five cowpea varieties grown at Wenchi in the three villages; Asuano, Beposo and Droboso. (a) Farmers' preference ranking after the first season experiments with cowpea and after they had planted varieties individually in their own fields; (b) Farmers' criteria for selection; and (c) Number of farmers selecting various cowpea varieties. (N.B. for a and b the lowest scores indicate the best variety.)

(a)

Variety	Natives				Migrants			
	Asuoano (n = 9)	Beposo (n = 5)	Droboso (n = 7)	Average rank	Asuoano (n = 5)	Beposo (n = 5)	Droboso (n = 7)	Average rank
<u>Group experiment</u>								
Asontem	2	2	1	1.7	4	3	3	3.3
Adom	1	3	3	2.3	2	4	4	3.3
Ayiyi	4	4	4	4.0	3	3	5	3.7
IT810D-1010	3	1	4	2.7	1	1	2	1.3
Legon prolific	5	5	2	4.0	5	5	1	3.7
<u>After individual farmers' planting</u>								
Asontem	2	2	2	2.0	4	3	3	3.3
Adom	1	3	3	2.3	2	4	5	3.7
Ayiyi	4	4	4	4.0	3	3	4	3.3
IT810D-1010	3	1	1	1.6	1	1	1	1.0
Legon prolific	5	5	5	5.0	5	5	2	4.0

(b)

Criteria	Ranking Natives (n = 21)	Migrants (n =17)
Market value	1	1
Short maturity period	2	3
Yield	3	2
Taste	5	4
Ease of harvesting (plant height above the ground)	4	6
Tolerance to insect pests	6	5
Seed size	7	7
Pod length	8	8

(c)

Variety	Number of farmers Natives (n = 10)	Migrants (n = 11)	Total (n = 21)	Percentage	Reason for selection
Asontem	6	4	10	48	High yielding, early maturing
Adom	5	0	5	24	High yielding
Ayiyi	0	2	2	10	Early maturing
IT810D-1010	2	6	8	38	Sweet taste, early maturing, good market
Legon prolific	0	3	3	14	Leaves used as vegetable

Table 6. Estimated costs of production, gross revenue and returns on investment of: a) five cowpea varieties and maize; b) a succeeding maize crop grown without added fertiliser after the first season cowpea varieties and maize; and c) cowpea/maize rotations and continuous maize cropping in Wenchi.

Cowpea variety or maize crop	Economic yield (t ha^{-1})	Price/tonne (US$)	Total revenue (US$ ha^{-1})[1]	Production costs (US$ ha^{-1}) Input	Production costs (US$ ha^{-1}) Labour	Total cost (US$ ha^{-1})	Net revenue (US$ ha^{-1})	Returns on investment (%)
a) Cowpea varieties and maize crop								
Asontem	1.08	375	405	47	171	219	186	85
Adom	1.14	449	512	47	173	220	292	132
Ayiyi	1.07	338	361	47	171	218	143	66
IT 810D-1010	1.09	564	614	47	171	219	396	181
Legon prolific	1.31	338	442	47	183	230	212	92
Maize	0.63	181	114	11	129	140	-26	-19
b) A succeeding maize crop grown after cowpea varieties and the maize crop								
Asontem	0.76	181	138	11	114	125	13	10
Adom	0.82	181	149	11	114	125	23	19
Ayiyi	0.96	181	174	11	115	126	48	38
IT 810D-1010	1.00	181	181	11	116	127	54	42
Legon prolific	1.46	181	264	11	127	138	126	92
Maize	0.38	181	69	11	111	122	-53	-44
c) Cowpea/maize rotations and continuous maize cropping								
Asontem			542	58	285	343	199	58
Adom			660	58	287	345	315	91
Ayiyi			535	58	286	344	191	55
IT 810D-1010			795	58.	288	346	449	130
Legon prolific			707	58	310	368	338	92
Maize			183	22	240	262	-79	-30

[1]Exchange rate used for Cedi to US$: US$1 = ¢9000

of 10-42% when grown after the other cowpea varieties (Table 6). Despite the farmers' recognition of the soil fertility benefits of the cowpea varieties in improving the yield of the subsequent maize crop, none of the farmer groups included this as an important criterion for selecting which cowpea varieties to grow (Table 5b). When the principal researcher asked farmers subsequently whether or not soil fertility improvement should be added to the list of criteria, the farmers responded negatively even if they were clearly aware that cowpea varieties differed in this respect. Hence in selecting a variety the farmers considered criteria such as marketability, suitability for food, labour requirement and maturity before considering other criteria such as soil fertility improvement. Our findings confirm the conclusions of Kitch *et al.* (1998) who reported that in Cameroon, farmers' acceptance criteria and preferences for cowpea varieties were strongly influenced by market preferences.

In the northern Guinea savanna of Nigeria, multi-purpose varieties of cowpea that combine characteristics of a good yield with prolific biomass production were found to be highly popular among farmers and rapidly spread from village to village (Inaizumi *et al.*, 1999). Multi-purpose varieties of other legumes such as soyabean have also been rapidly adopted by farmers in both west (Sanginga *et al.*, 1999) and southern Africa (Mpepereki *et al.*, 2000). Reasons often stated for farmers' interest in such multi-purpose varieties is the provision of fodder for livestock, improved soil fertility as well as grain for food or sale (for a detailed discussion see Chapter 13 of Giller, 2001). In the Wenchi region, livestock play a minor role and are poorly integrated in the farming systems which probably explain why forage production is not a criterion for selection of cowpea varieties.

4.5. Conclusions

Our results clearly demonstrate the direct benefits of N_2-fixation in cowpea in terms of grain production and the increased residual soil fertility benefits of a creeping forage cowpea variety above the erect varieties. However, although farmers observed the soil fertility benefits of growing cowpea, and this was supported by economic analyses, they did not include this as a criterion in making their variety choice. The overriding criteria for selecting cowpea varieties were related to their early harvest, seed quality in terms of taste and marketability and ease of production (low labour demand). Our results thus confirm the suggestion (Giller, 2001) that soil fertility benefits of legumes must be considered as an 'additional benefit' rather than a primary criterion when designing more sustainable cropping systems together with smallholder farmers in Africa.

References

Adjei-Nsiah S., Leeuwis, C., Giller, K.E., Sakyi-Dawson, O., Cobbina, J., Kuyper, T.W., Abekoe, M. and Van der Werf, W., 2004. Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: implications for interdisciplinary action research. NJAS-Wageningen Journal of Life Sciences, 52:331-348.

Adjei-Nsiah S., Leeuwis, C., Sakyi-Dawson, O., Giller, K.E. and Kuyper, T.W., 2006. Exploring diversity among farmers for orienting interdisciplinary action research on cropping system management in Wenchi, Ghana: the significance of time horizons. International Journal of Agricultural Sustainability (Accepted).

Asiamah, R.D., Adjei-Gyapong, T., Yeboah, E., Fening, J.O., Ampontuah, E.O. and Gaise, E., 2000. Report on Soil Characterization and Evaluation at four Primary Cassava Multiplication Sites (Mampong, Wenchi, Asuansi and Kpeve) in Ghana. Technical Report No. 200. Soil Research Institute, Kumasi.

Awonaike, K.O, Kumarasinghe, K.S. and Danso, S.K.A., 1990. Nitrogen fixation and yield of cowpea (*Vigna unguiculata*) as influenced by cultivar and *Bradyfrizobium strain*. Field Crops Research, 24: 163-171.

Bank of Ghana, 2005. Periodic Economic Reports: Half year Economic Review 2005 (Provisional Data) www.bog.gov.gh accessed on 2nd June, 2006.

Becker, M. and Johnson, D.E., 1998. Legumes as dry season fallow in upland rice-based systems of West Africa. Biology and Fertility of Soil, 27: 358-367

Carsky, R.J., Oyewole, B. and Tian, G. 1999. Integrated soil management for the savanna zone of W. Africa: Legume rotation and fertilizer N. Nutrient Cycling in Agroecosystems, 55: 95-105.

Dakora, F.D., Aboyinga, R.A., Mahama, Y. and Apaseku, J., 1987. Assessment of N_2-fixation in groundnut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata* L. Walp) and their relative N contribution to a succeeding maize crop in Northern Ghana. MIRCEN Journal, 3:389-399.

Eaglesham, A.R.J., Ayanaba, A., Ranga Rao, V. and Eskew, D.L., 1982. Mineral N effects on cowpea and soybean crops in a Nigerian soil II. Amounts of N fixed and accrual to the soil, Plant and Soil 68: 183-192.

Francis, C.A. and Clegg, M.D., 1990. Crop rotation in sustainable production systems. In: C.A. Edwards, R. Lal, P. Madden, R.H. Miller and G. House (Eds), p. 107-122. Sustainable agricultural systems. Soil and Water Conservation Society, Ankeny.

Gerner, H., Asante, E.O., Owusu Bennoah, E. and Marfo, K., 1995. Ghana Fertilise Privatization Scheme. Private Sector Role and Public Sector Responsibilities in Meeting Needs of Farmers. IFDC-Africa, Lome, Togo.

Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems. CAB International, Wallingford.

Giller, K.E. and Cadisch, G. 1995. Future benefits from biological nitrogen fixation: An ecological approach to agriculture. Plant and Soil, 174: 255-277.

Harinikumar, K.M. and Bagyaraj, D.J., 1988. Effect of crop rotation on native vesicular arbuscular mycorrhizal propagules in soil. Plant and Soil, 110: 77-80.

Inaizumi, H., Singh, B.B., Sanginga, P.C., Manyong, V.M., Adesina, A.A. and Tarawali, S.A., 1999. Adoption and Impact of Dry-season Dual-purpose Cowpea in the Semiarid Zone of Nigeria. IITA, Ibadan, Nigeria.

ISSER, 2005. State of the Ghanaian Economy for 2004. Institute for Social, Statistical and Economic Research, University of Ghana, Legon.

Kitch, L.W., Boukar, O., Endondo, C. and Murdock, L., 1998. Farmer acceptability criteria in breeding cowpea. Experimental. Agriculture. 34: 475-486.

Mpepereki, S., Javaheri, F., Davis, P. and Giller, K.E., 2000. Soyabeans and sustainable agriculture: 'Promiscuous'soyabeans in southern Africa. Field Crops Research, 65: 137-149.

Nguluu, S.N., Probert, M.E., McCown, R.L., Myers, R.J.K. and Waring, S.A., 2002. Isotopic discrimination associated with symbiotic nitrogen fixation in stylo (*Stylosanthes hamata* L.) and cowpea (*Vigna unguiculata* L). Nutrient Cycling in Agroecosystems, 62: 10-13.

Nye, P.H. and Stephens, D. 1962. Soil fertility. In: Wills, J.B. (Ed.), Agriculture and Landuse in Ghana, pp. 127-143, Oxford University Press, London.

Offei, S.K. and Sakyi-Dawson, O., 2002. Technographic studies on cowpea as a private sector crop in Ghana. Online document at URLhttp://www.dpw.wageningen-ur.nl/forum Accessed 12 September, 2002

Ofori, F., Pate, J.S. and Stern, W.R., 1987. Evaluation of N_2-fixation and nitrogen economy of a maize/cowpea intercrop system using 15N dilution methods. Plant and Soil, 102: 149-160.

Peoples, M.B. and Craswell, E.T., 1992. Biological nitrogen fixation: Investments, expectations and actual contributions to agriculture. Plant and Soil, 141: 13-39.

Peoples, M.B., Faizah, A.W., Rekasem, B and Herridge, D.F. (Eds.), 1989. Methods for Evaluating Nitrogen Fixation by Nodulated Legumes in the Field. ACIAR, Canberra.

Sanginga, P.C., Adesina, A.A., Manyong, V.M., Otite, O. and Dashiell, K., 1999. Social Impact of Soybean in Nigeria's Southern Guinea Savanna. IITA, Ibadan, Nigeria.

SAS, 1996. SAS User's Guide: Statistics. SAS Institute, Cary, NC.

Sisworo, W.H., Mitrosuhardjo, M.M., Rasjid, H. and Myers, R.J.K., 1990. The relative roles of N fixation, fertiliser, crop residues and soil in supplying N in multiple cropping systems in a humid, tropical upland cropping system. Plant and Soil, 121: 73-82.

Unkovich, M.J. and Pate, J.S., 2000. An appraisal of recent field measurements of symbiotic N_2-fixation by annual legumes. Field Crops Research, 65: 211-228.

CHAPTER 5

Cassava improves soil fertility? Farmers' soil fertility management practices in the forest/savannah transitional agro-ecological zone of Ghana

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Abstract

Crop rotations are important crop management practices among small-holder farmers in the forest/savannah transitional agro-ecological zone of Ghana for regenerating soil fertility. Six cropping sequences; cassava, pigeonpea, mucuna-maize-mucuna, cowpea-maize-cowpea, maize-maize-maize and speargrass fallow were evaluated in 2003-2004 in Wenchi district of Ghana for their effects on the productivity of subsequent maize crop and the profitability of the different rotational sequences. Soil chemical properties were not significantly affected by cropping sequence. On the researcher-managed and farmer-managed plots maize grain yields were significantly ($P<0.01$) influenced by cropping sequence. On the researcher-managed plots maize grain yield ranged from 1.0 t ha^{-1} after speargrass fallow to 3.0 t ha^{-1} with cassava cropping when N fertiliser was not applied to the maize crop and then from 2.1 t ha^{-1} with continuous maize to 4.2 t ha^{-1} with mucuna-maize-mucuna when 60 kg N ha^{-1} was applied to the maize. On the farmer-managed plots where N fertiliser was not applied to maize, maize grain yields ranged from 0.4 t ha^{-1} with speargrass fallow to 2.2 t ha^{-1} with plots previously cropped to pigeonpea. Return on investment of the different rotational sequences ranged from 29% with continuous maize to 196% with cassava/maize when N fertiliser was applied to maize and then from -22% with speargrass / maize to 235% with cassava/maize when no N application was made to the maize crop. Cassava/maize rotation was ranked by the native farmers as the most preferred rotation whereas the migrant farmers ranked cowpea-maize-cowpea-maize as the most preferred rotation. Among natives, male farmers ranked rotation involving cowpea as the next most preferred rotation after cassava/maize rotation. In contrast, female farmers ranked peageonpea/maize rotation as the second most preferred rotation, due to low labour and external input requirements of pigeonpea compared to cowpea. It appears that the choice of a particular rotational sequence is more related to access to resources and the needs of the farmer. The study therefore suggests that, in a heterogeneous farming community like Wenchi, technology development should be targeted to suit the needs and resources available to each particular group of farmers.

5.1. Introduction

Farmers in the forest/savannah transitional agro-ecological zone of Ghana use various farming practices to regenerate the fertility of their farmland. Prominent among these practices are rotations with crops such as cowpea (*Vigna unguiculata* L. (Walp)), pigeonpea (*Cajanus cajan* L.) and cassava (*Manihot esculenta* Crantz). Cassava is usually cropped for a period ranging from 18 to 24 months after which period the land − according to the farmers − is rejuvenated. Saidou et al. (2004) also reported that farmers in the forest/savannah transitional agro-ecological zone of Benin use cassava cropping as a soil fertility regenerating strategy.

Legumes improve soil fertility because of their N_2 fixing ability (Peoples and Craswel, 1992; Peoples et al., 1995; Giller and Cadisch, 1995; Giller, 2001; Crews and Peoples, 2004). By contrast, the use of cassava as a soil fertility regenerating crop seems to contradict with a claim made by several researchers that cassava impoverishes soils (Hendershott et al., 1972 cited by Nweke et al., 2002; Sitompul et al., 1992; Budidarsono et al., 1998). However, several studies (Putthacharoen et al., 1998; Howeler and Cadavid, 1983; Howeler, 1991; Howeler, 2002) have demonstrated that cassava removes less of N and P per ton of dry product than most crops and a similar amount of K. The amount of nutrients removed in the tuber (storage root) harvest is, however, highly dependent on growth rate and yield which in turn depends on climate, soil fertility conditions and variety (Howeler, 2002). Nweke et al. (2002) reported that soil samples collected from fields cropped to staple crops in six countries in Africa showed that soils of cassava fields were higher in total nitrogen, organic matter, calcium, sodium, total exchangeable bases and pH. Howeler (2002) concluded that the idea that cassava is a 'scavenger' crop, efficient in nutrient capture and removal, results from its ability to grow on depleted and degraded soils where other crops fail.

Despite the widely acclaimed potential of some of these farmers' management practices in restoring soil fertility, comparative studies to assess their effects on soil properties and maize yields in the forest/savannah transitional zone are lacking. In a previous study (Adjei-Nsiah et al., 2004), we found that native and migrant farmers use different crop management practices due to their different land tenure arrangements. For instance, the study revealed that native farmers use long-term crop management practices such as bush fallow and rotations with cassava and pigeonpea while migrant farmers rely on short-term management practices such as ridging and mounding and rotation with short duration crops such as cowpea.

The objective of this study was to compare the productivity of these crop sequences under both researcher-managed and farmer-managed experiment. We further examined the socio-economic and institutional factors that influence the use of these practices and draw out implications of the study for the development of soil fertility management technologies for smallholder farmers.

5.2. Materials and methods

5.2.1. Study site

The study was conducted in three communities, namely Asuoano (7^{o}41´ N, 2^{o}05´ W), Beposo (7^{o}42´ N, 2^{o}05´ W) and Droboso (7^{o}43´ 2^{o}05´ W) near Wenchi in the Brong-Ahafo Region of Ghana. Wenchi is located in the forest /savannah transitional agro-ecological zone of Ghana. The study site is characterised by a bimodal rainfall pattern with a 30-year average of 1271 mm. The major growing season is from April to July and a minor growing season is from September to November followed by a dry season from December to March. The annual rainfall amounts during the study period were 1396 mm (2003), 1350 mm (2004) and 1330 mm (2005). The soils which developed on Voltaian sandstone (coarse-grained type) are mainly Lixisols (Asiamah et al., 2000). The topography is gently flat to undulating and soils are well drained, friable, porous and sandy loams.

5.2.2. Researcher-managed experiment

The experimental plot had been under continuous maize cropping for three years (1999-2001) and had been abandoned for one year (2002) due to poor soil fertility and high infestation of speargrass (*Imperata cylindrica*). The initial land preparation consisted of harrowing after first and second ploughing. The trial consisted of six treatments replicated four times in four blocks. The treatments consisted of mucuna-maize-mucuna rotation, cowpea-maize-cowpea rotation, 16 months pigeonpea cropping, 16 months cassava cropping, 16 months speargrass fallow and three seasons continuous maize (*Zea mays*) cropping. The crop sequences of the various treatments and the monthly rainfall distribution during the experimental period is presented in Figure 1. The pigeonpea and cassava varieties used were local varieties which have maturity periods of 40 and 72 weeks respectively. Cowpea variety Asontem and maize variety Dorke SR were used in the rotations. Composite soil samples were collected from 0-20 and 20-40 cm soil depths before treatments were implemented.

Plot size was 12 m × 10 m. There were 3 m alleys between plots and replicates. Distance between cowpea rows was 60 cm and distance within rows was 20 cm. Mucuna (*Mucuna pruriens*) and maize were planted at a spacing of 80 cm × 40 cm while cassava and pigeonpea were planted at 100 cm × 50 cm. Two seeds per hill were maintained for maize, mucuna, cowpea and pigeonpea. Planting of cassava and pigeonpea and first season planting of mucuna, cowpea and maize was done in the last week of April, 2003.

Six months after planting, 5 litter traps each measuring 50 cm × 50 cm and raised about 50 cm from the ground were placed under the cassava and pigeonpea canopies to trap fallen leaf litter. The litters were collected every four weeks, oven dried at 70^{o}C for 2 days for dry matter determination.

At each harvest of the cowpea, an area of 10.8 m^2 (3 rows of 6 m) was harvested when the crop was mature. The vines and pods were separated and the pods were dried and shelled. The fallen leaf litter was collected from the harvest area of cowpea. Sub-samples of all harvested samples were taken and oven-dried at 70^{o}C for 2 days to determine dry matter contents. The stover comprising the litter and vines were ploughed into the soil by hand using a hoe.

Mucuna biomass was always slashed at approximately 120 days after planting using a cutlass. Samples were taken from the central 3 m × 2.4 m of each plot and weighed. The biomass was then incorporated into the soil by hand using a hoe after taking samples for DM determinations.

At maturity, maize ears and stover harvested from the 6 central rows of each sub-plot, leaving a 1 m border at both ends, were weighed. A sub-sample of 10 cobs per plot was taken and oven dried at 70^{o}C for 2 days. The grains were then removed and weighed again to determine the DM. The stover was weighed fresh and sub-samples taken to determine the DM. The remaining biomass was then incorporated into the soil by hand using a hoe.

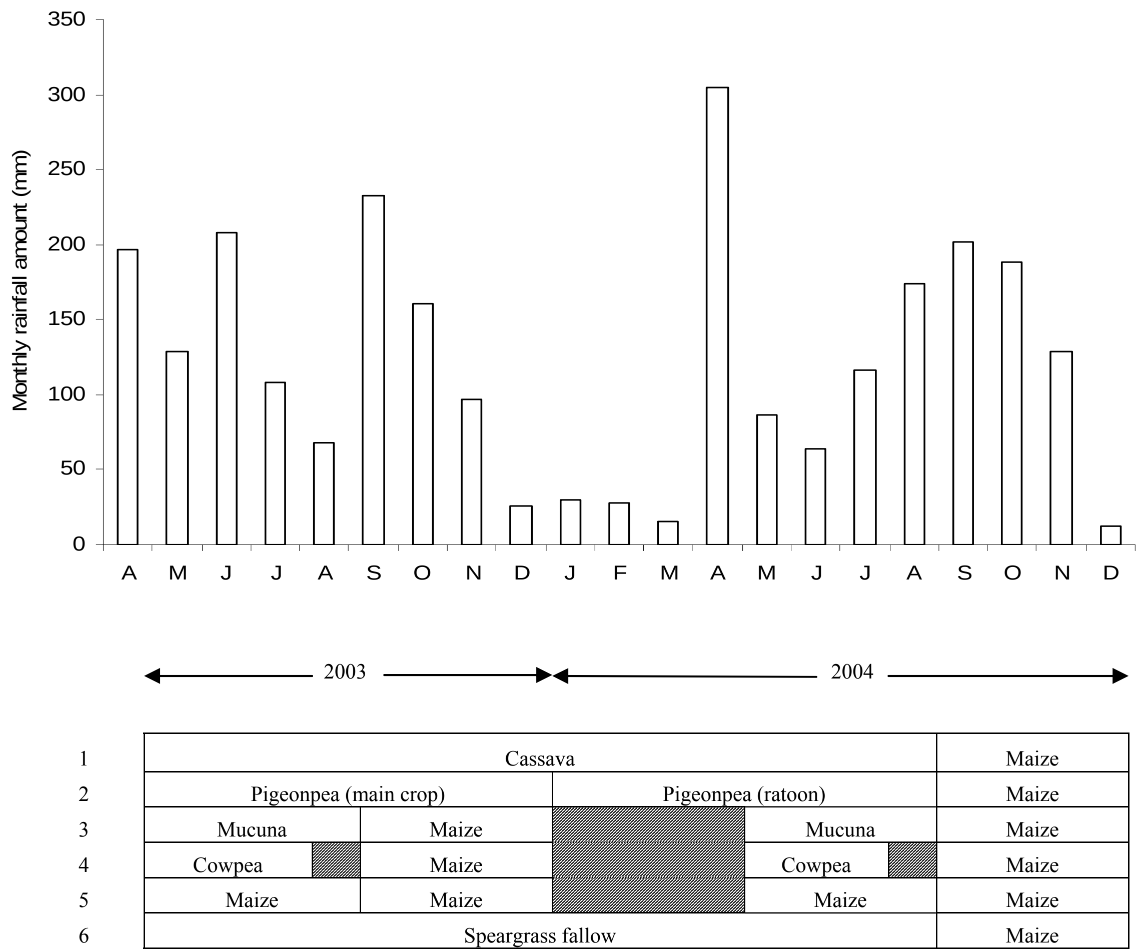

Figure 1. Crop sequences and monthly rainfall distribution during the experimental period (Shaded portions represent fallowed periods).

In February, 2004, the pigeonpea grains were harvested; the plants were cut back at 30 cm from the ground, the materials were separated into shoots with diameter >15 mm and shoots with diameter<15 mm and weighed separately. Samples of each component were taken for DM determination. The biomass with diameter <15 mm was left on the plot to decompose. In August, 2004, pigeonpea was cut back again. The plants were separated into leaves and young (succulent with diameter <5 mm) and old (with diameter >5 mm) shoot materials and each weighed separately. Samples of each component were shredded into pieces and sub-samples taken for DM determination. The stems with diameter >5 mm were removed while the shoot material with diameter <5 mm were incorporated into the soil by hoe. During the same period which was approximately 62 weeks after planting, an area of 12 m^2 (2 rows of 6 m) of the cassava plot was harvested. The plants were separated into roots, stems and foliage and weighed. Sub-samples of all harvested components were taken and oven dried at 70^{o}C for 2 days for dry matter determination. After harvesting the whole plot, the roots and the stems were removed and the green biomass incorporated into the soil using hoe. The speargrass fallow vegetation was slashed with a cutlass and the biomass incorporated into the soil using a hoe after taking samples to determine dry matter.

Sub-samples of plant parts of all component crops in the various crop sequences were analysed for nitrogen (N). These plant parts were then grouped into two categories: (1) plant parts that would normally be removed from the field in the harvested products; and (2) plant parts that would remain in the field and be incorporated into the soil. The amounts of DM and nutrients that were either removed from the field or reincorporated into the soil were also calculated.

In September, 2004, maize variety, 'Abeleehi' was planted on all the plots at a distance of 80 cm × 20 cm with 3 seeds per hole. The maize pockets without germination were replanted 10 days after the first planting. The stand was thinned to one plant per hill at 2 weeks after planting. All plots were split into 2 sub-plots, which received 0 and 60 kg N ha^{-1} as ammonium sulphate in two split applications: half at 14 days and half at 42 days after planting. Weeding was done at 4 and 8 weeks after planting. Before the maize was planted, soil samples were taken from 0-20 and 20-40 cm depth layers of the soil.

At maturity, maize ears and stalks were harvested from the six central rows of each sub-plot, leaving a 1 m border at both ends, and weighed. A sub-sample of 10 cobs per plot was taken, weighed and oven-dried at 70 ^{o}C for 2 days. The dry grains were removed and weighed again to determine the grain DM.

Incorporation of residues into the soil was made by the same person. The time spent for incorporating the residue of each treatment into the soil was recorded, summed per treatment and converted to man-hours. Weed biomass in the respective treatments was assessed during the second weeding which was done at 8 weeks after planting. Measurements were taken in 0.5 m × 0.5 m quadrats at three locations in each subplot. Weeds were hand picked, oven-dried at 70^{o}C for 2 days and biomass determined.

In April, 2005, a maize variety 'Abeleehi' was planted on plots previously under speargrass fallow/maize, continuous maize, cassava/maize and pigeonpea/maize rotations to study the residual effects of these rotations on the yield of subsequent maize.

5.2.3. Farmer-managed experiments

Farmer groups in each of the communities were composed of both migrant and native farmers. Selection of farmers was based on interest and preparedness to spend one day in a week on the experimental field. The composition of farmers in the various groups was as follows: Asuoano (9 natives, 8 migrants); Beposo (6 natives, 6 migrants) and Droboso (8 natives and 7 migrants). The experiments were conducted on collective plots in each of the communities.

Land preparation on farmers' fields consisted of ploughing by tractor followed by harrowing using hoes. On the farmer-managed plots two additional treatments namely groundnut-maize-groundnut and three seasons continuous cowpea were included by the farmers in addition to the six treatments used in the researcher-managed experiments. Planting, field management and harvesting decisions were made by farmers. All participating farmers in each of the communities met with the researcher and decided when to plant, spray with insecticide and harvest. The idea of having the experiments on collective plots was moved by the farmers. There were no replications within each experiment. Instead, each community represented a replicate.

Litter traps measuring 50 cm × 50 cm and raised 50 cm above the ground were placed under the canopies of the cassava and pigeonpea plots to trap falling leaf litter. The litters were weighed together with the farmers every four weeks to determine the amount of litter produced. On the farmer-managed plots, pigeonpea biomass and the biomass on the fallowed plots were burnt because farmers argued that incorporating the green biomass in the soil will be expensive and time consuming and leaving it on the soil surface as mulch will make working on the field too difficult. After harvesting the cassava, the biomass was left in the sun on the land for one week for the leaves to dry and shed on the soil. The stems were removed from the plots and the shed leaves incorporated into the soil by hand using hoe. The cowpea, groundnut and the mucuna biomass were incorporated into the soil by hand hoe. Initially farmers were reluctant to incorporate the mucuna biomass into the soil. They argued that on the large scale it would be laborious to incorporate it into the soil as tractor services are also not readily available in the area.

In August 2004, a local maize variety (var. Abeleehi) was planted on all the plots to assess the beneficial effects of the various treatments on the subsequent maize yield. Weed control on farmers' plot was done twice; at 6 and 10 weeks after planting.

The beneficial effect of the different crop sequences on maize grain yield was assessed with the farmers through ranking and scoring as well as by harvesting and weighing the grains produced. Each treatment was compared directly against the others until they were ranked from the highest to the lowest. Later, the different categories of farmers (i.e. native and migrant farmers and male and female Bono farmers) in the three different communities were asked to rank the different rotations. Each rotation was compared directly against the others until they were ranked from the rotation the farmers preferred best, to the rotation they considered the least preferred.

5.2.4. Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure (SAS, 1996).

5.2.5. Economic analysis

A simple financial analysis was performed to evaluate the profitability of each of the crop sequences. The analysis included total revenue and cost of production per hectare for crops in each crop sequence and that of maize crop succeeding the crop sequence when N fertiliser is applied to the maize crop or not. From this, net revenues for crops in each sequence as well as that for maize test crop succeeding it when N fertiliser is applied to the maize crop or not were determined. The net revenue from the investment was given by: NR=TR-TC
Where NR is the net revenue; TR, total revenue; and TC is total cost.
Returns on investment (RI) were also computed thus: RI = NR/TC
Where an RI > interest rate on capital implies profitability.

Economic yields for grain legumes and maize were based on 12% moisture content while that of cassava was based on fresh weight. Costs of production were divided into land, inputs and labour for field activities and transport of farm produce to the house. Costs of inputs were determined based on the prices of local planting materials and fertilisers. Costs of labour for most of the field operations were determined together with the collaborative farmers based on existing labour rates in the communities. Certain field operations such as incorporation of green biomass of mucuna and pigeonpea into the soil were however, estimated in terms of the time requirements for incorporation into the soil and the daily labour rate. All amounts of money are expressed in US dollars at the average exchange rate between December, 2003 to June, 2005 : ¢9000 to US$1 (Bank of Ghana, 2005). With the exception of pigeonpea where the price was based on the prevailing market price in the communities, prices for the other food crops were based on the national average wholesale price between 2002 and 2004 (ISSER, 2005).

5.3. Results

5.3.1. Soil chemical properties

The organic carbon at the start of the experiment was 0.84 (0-20) and 0.60 (20-40 cm depth) % in 2003 (Table 1) compared to an average of 0.76 (0-20) and 0.50 (20-40 cm depth) % in 2004 (Table 2). Similarly total soil N was 0.12 (0-20) and 0.08 (20-40 cm depth) % in 2003 and 0.08 (0-20) and 0.05 (20-40 cm depth) % at the end of the experiment. Soil pH did not change very much during the period. Exchangeable K was 0.21 (0-20) and 0.16 (20-40 cm depth) cmol kg^{-1} in 2003 and on average of 0.1(0-20) and 0.05 (20-40 cm depth) cmol kg^{-1} after three cropping seasons. The amounts of exchangeable Ca and Mg were higher after three cropping seasons. Crop sequences did not have any significant effect on soil pH, organic carbon and total N. However, the crop sequences differed in their effect on available P. The available P in the cassava and maize-maize-maize systems was the highest and in the pigeonpea system the lowest.

Table 1. Initial soil characteristics of the 0-20 and 20-40 cm layers of the soil of researcher-managed and farmer-managed plots before the commencement of the experiment in 2003 at Wenchi.

Soil depth (cm)	pH ($H_2$0)	OC (%)	N (%)	P (mg kg^{-1})	Ca ($cmol_{(+)}$ kg $^{-1}$)	Mg	K	Sand %	Silt	Clay
Researcher-managed experiment										
0-20	6.0	0.84	0.12	6.4	2.2	1.2	0.21	76	9	15
20-40	6.0	0.60	0.08	3.9	1.7	0.8	0.16	76	9	15
Farmer-managed experiment										
0-20	5.6	0.74	0.08	6.1	2.0	1.9	0.22	76	7	17
0-40	5.8	0.43	0.07	3.3	1.5	1.4	0.12	72	6	22

5.3.2. Dry matter production and N contribution to the system

The amount of dry matter produced in the various crop sequences ranged from 7.5 t ha^{-1} with maize-maize-maize cropping to 39.0 t ha^{-1} with pigeonpea cropping (Table 3). Cassava produced 31.5 t ha^{-1} of DM, of which about 70% was removed from the field as storage roots and stems. Mucuna-maize-mucuna also had a relatively high production of dry matter (20.1 t ha^{-1}) with less than 10% removed from the field as maize grain. Cowpea-maize-cowpea and maize-maize-maize produced relatively less DM (9.8 and 7.5 t ha^{-1} respectively) than all the other systems, with 35 and 40%, respectively, being removed from the system. The

Table 2. Effect of crop sequence on chemical and physical properties of soils sampled before planting of maize test crop in September, 2004.

Soil depth (cm)	pH (H_20)	OC (%)	Total N (%)	Avail P (mg kg^{-1})	Ca ($cmol_{(+)}$ kg^{-1})	Mg	K	Sand %	Silt	Clay
0-20										
Cassava	6.2	0.74	0.08	5.2	2.8	2.6	0.11	73	7	20
Pigeonpea	6.1	0.76	0.08	3.8	2.6	2.4	0.10	72	9	19
Mucuna/maize/*Mucuna*	6.1	0.76	0.07	4.5	2.9	2.7	0.09	71	8	21
Maize/maize/maize	6.1	0.79	0.07	5.3	2.9	2.8	0.10	73	9	18
Speargrass fallow	6.2	0.75	0.08	4.0	2.8	2.2	0.09	72	9	19
Cowpea-maize-cowpea*										
Pr>F	NS	NS	NS	0.01	NS	0.05	0.05	NS	NS	NS
SED	0.07	0.07	0.009	0.39	0.19	0.19	0.05	1.3	1.1	1.4
20-40										
Cassava	6.1	0.50	0.05	2.5	1.7	1.5	0.05	73	8	19
Pigeonpea	6.1	0.46	0.05	2.0	1.1	1.2	0.05	72	9	19
Mucuna/maize/*Mucuna*	6.0	0.47	0.04	2.2	1.3	1.1	0.05	73	7	20
Maize/maize/maize	6.0	0.56	0.05	2.9	1.7	1.3	0.05	73	8	19
Speargrass fallow	6.0	0.50	0.05	2.0	1.5	1.4	0.05	72	9	19
Cowpea-maize-cowpea*										
SED	0.06	0.04	0.006	0.28	0.23	0.23	0.006	1.0	0.7	1.2
Pr>F	NS	NS	NS	0.05	NS	NS	NS	NS	NS	NS

* Data not available

Table 3. Dry matter (t ha^{-1}) and N content (kg ha^{-1}) of plant parts removed in the crop harvest and those returned to the soil for the six crop sequences during the different cropping seasons before the final maize test crop

Crop sequence	April-Aug '03		Sep-Nov '03		Dec '03-Mar '04		Apr-Aug '04		Total	
	DM	N	DM	N	DM	N	DM	N	DM	N
Plant parts of the harvested crop removed from the field										
Cassava	-	-	-	-	-	-	22.7	244	22.7	244
Pigeonpea	-	-	-	-	11.2	165	2.5	31	13.7	196
Mucuna-maize-mucuna	-	-	1.8	29	-	-	-	-	1.8	29
Cowpea-maize-cowpea	1.5	48	1.1	18	-	-	0.8	26	3.4	92
Maize-maize-maize	2.0	32	0.5	8	-	-	0.5	8	3.0	48
Speargrass fallow	-	-	-	-	-	-	-	-	-	-
SED									1.5	27
Pr< F									<0.0001	<0.0001
Plant parts of the harvested crop returned to the field										
Cassava	-	-	0.7	13	2.8	53	5.3	157	8.8	223
Pigeonpea	-	-	2.0	37	17.9	279	5.6	128	25.5	444
Mucuna-maize-mucuna	8.8	179	2.5	20	-	-	7.0	142	18.3	341
Cowpea-maize-cowpea	3.6	62	1.6	13	-	-	1.2	21	6.4	96
Maize-maize-maize	2.6	21	0.7	6	-	-	1.2	10	4.5	37
Speargrass fallow	-	-	-	-	-	-	12.7	171	12.7	171
									1.7	28
SED										
Pr<F									<0.0001	<0.0001

speargrass fallow system produced a considerable amount of dry matter (12.7 t ha^{-1}) with all of it being returned to the plot.

The total amount of N accumulated by the various crop sequences before the maize test crop was planted ranged from 85 kg N ha^{-1} with maize-maize-maize cropping to 640 kg N ha^{-1} with the pigeonpea cropping (Table 4). While pigeonpea, mucuna-maize-mucuna and cowpea-maize-cowpea obtained a substantial amount of their N (448, 225 and 110 kg N ha^{-1} respectively) through N_2-fixation, cassava cropping, maize-maize-maize and speargrass obtained all their N requirements from the soil (Table 4)

The amount of N removed from the system through crop harvest and removal of woody stems that were not returned to the field ranged from 48 kg N ha^{-1} with maize-maize-maize cropping to 244 kg N ha^{-1} with cassava cropping (Tables 3 and 4). The amounts of N that were recycled in the various systems through incorporation of crop residues were 37, 96, 171, 223, 341 and 444 kg ha^{-1} for maize-maize-maize, cowpea-maize-cowpea, speargrass fallow, cassava cropping, mucuna-maize-mucuna and pigeonpea cropping (Tables 3 and 4). This resulted in a net N balance of -244, -48, 0, 18, 196 and 252 for cassava cropping, maize-maize-maize, speargrass fallow, cowpea-maize-cowpea, mucuna-maize-mucuna and pigeonpea cropping after adjusting for removal through crop harvest and woody stems that were not returned to the field (Table 4).

The amounts of N returned into the soil by the various crop sequences just before the maize test crop was planted were 10, 21, 128, 142, 157 and 171 kg N ha^{-1} for maize-maize-maize, cowpea-maize-cowpea, pigeonpea, mucuna-maize-mucuna, cassava and speargrass fallow respectively (Table 3). About 110, 142 and 123 kg N ha^{-1} of these amounts were returned into the soil in the form of green manure by pigeonpea, mucuna and cassava (data not shown). Decomposition data indicated that 6 weeks after incorporation of biomass (when maize was planted), only 15% of cassava litter remained. Of the legumes 5% of cowpea litter remained, 30% of mucuna, while the pigeonpea disappearance rate was slowest, with 75% remaining after 6 weeks. N mineralization rates were not determined.

5.3.3. Maize yield

On the researcher-managed plots, statistically significant ($P<0.01$) differences in maize grain yield were found between crop sequences (Figure 2). On the unfertilised plots maize grain yield ranged from 1.0 t ha^{-1} with speargrass fallow to 3.0 t ha^{-1} with plots previously under cassava cropping, and on the fertilised plots the yield ranged from 2.1 t ha^{-1} with the maize-maize-maize system to 4.2 t ha^{-1} with the mucuna-maize-mucuna system. A significant interaction between crop sequence and N application was found with maize grain yield.

Nitrogen application generally increased maize grain yield except in the cassava system where application of N resulted in a 9% decrease in maize grain yield. The increases in maize grain yield with N fertiliser application were 23, 39, 41, 54 and 174% for plots previously under pigeonpea, cowpea-maize-cowpea, mucuna-maize-mucuna, maize-maize-maize and speargrass fallow respectively.

On the farmer-managed plots where no fertiliser was applied, significant ($P<0.01$) differences in yield were also found with crop sequences. Yields were however generally smaller, ranging from 0.4 t ha^{-1} on speargrass fallow plots to 2.2 t ha^{-1} on plots previously under pigeonpea cropping (Figure 3).

In 2005, maize grain yield was significantly influenced by previous crop rotation and N rate. However, yields were generally poor due to a severe two weeks drought which occurred during the tasselling period in early July. On the plots where no N was applied, maize grain yield ranged from 0.8 t ha^{-1} on plots previously under speargrass fallow / maize rotation to 1.6 t ha^{-1} on plots previously under pigeonpea / maize rotation. On the fertilised plots, maize grain yield ranged from 1.2 t ha^{-1} after continuous maize to 2.1 t ha^{-1} after speargrass fallow/maize rotation.

The crop sequence also had a significant effect on dry matter of maize three weeks after planting. The effect of N-addition was also significant, but contrary to final yield, the interaction was not. Maize dry matter 3 weeks after planting was highest after cassava and lowest after speargrass fallow (Table 5). The number of days to 50% tasselling was significantly affected by crop sequence, N application, and the interaction. Maize tasselling took least time after cassava and most after speargrass fallow. Maize tasselling was very late after speargrass fallow when no fertiliser was applied (Table 5).

Table 4. N sources and net N contribution (kg N ha^{-1}) to the overall soil N economy of different crop sequences preceding the final maize test crop

Crop sequence	Total plant N	N sources		N removal through harvest	N recycled through crop residues	Net N Balance
		N from soil	N from fixation[a]			
Cassava	467	467	0	244	223	-244
Pigeonpea	640	192	448	196	444	252
Mucuna-maize-mucuna	370 (321)	145	225	29	341	196
Cowpea-maize-cowpea	188 (157)	78	110	92	96	18
Maize-maize-maize	85	85	0	48	37	-48
Speargrass	171	171	0	0	171	0
SED	49	36	25	27	28	25
Pr>F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Figures in brackets are amounts of N from the Legumes

[a]The legumes are assumed to have fixed 70% of their nitrogen

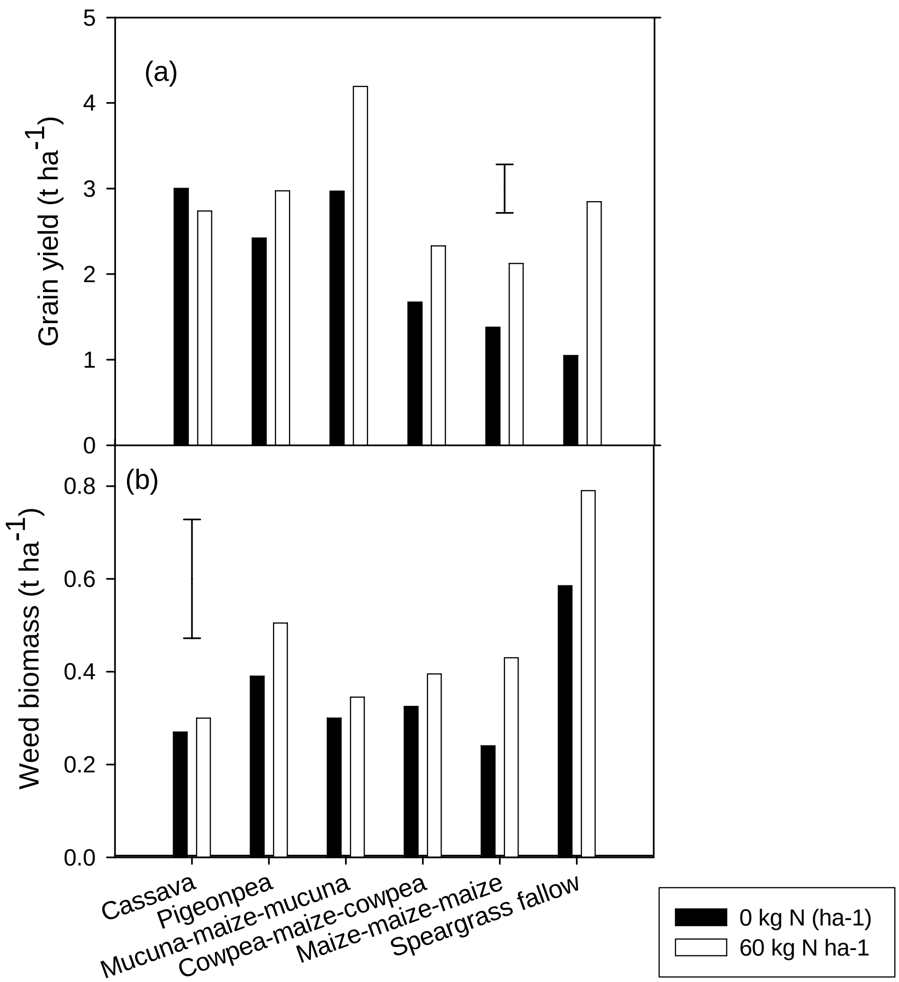

Figure 2 Effect of crop sequence and N rate on maize a) grain and b) weed biomass associated with the maize crop at 8 weeks after planting on researcher-managed plots. The vertical error bars refer to SED (Standard error of difference) bars

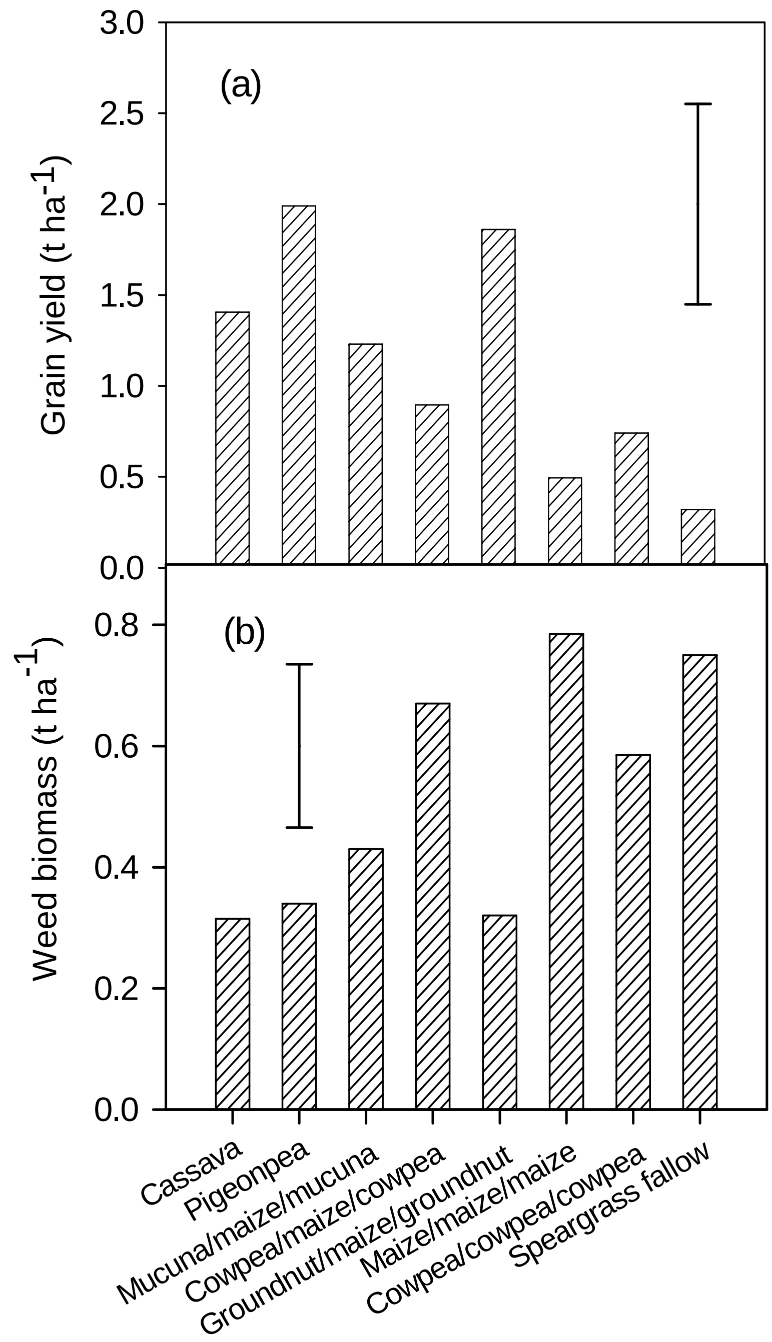

Figure 3 Effect of crop sequence on maize a) grain and b) weed biomass associated with the maize crop at 10 weeks after planting on farmer-managed plots. The vertical error bars refer to SED (Standard error of difference) bars

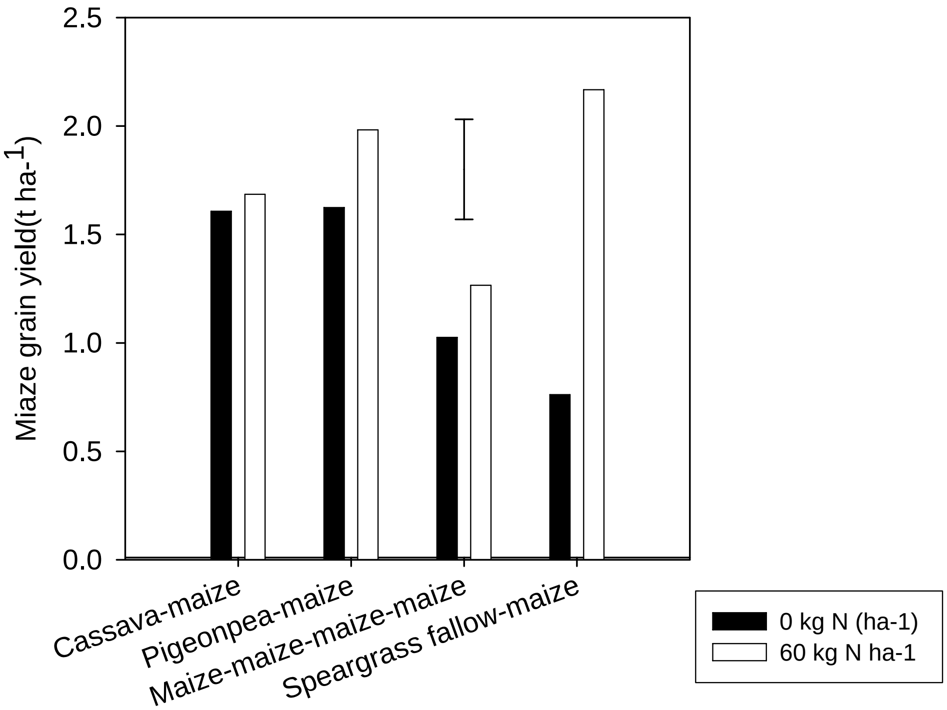

Figure 4 Effect of previous crop rotation and N rate on maize grain yield on researcher-managed plots. Vertical error bars refer to SED (Standard error of difference) of two crop sequence means at the same or different N rates.

5.3.4. Effect of crop sequence and mineral fertiliser application on weeds in maize crop

Crop sequence and fertiliser application both influenced weed biomass associated with maize crop (Figure 2). On both the researcher and farmer-managed fields, higher weed biomass was associated with maize crop grown on plots previously under speargrass fallow whereas less weed biomass was associated with the maize crop grown on plots previously under cassava cropping. Weed biomass after cassava in the unfertilised plots was roughly half that found after the speargrass fallow and further reduced to a third of that found after speargrass when cassava was

Table 5. Effect of crop sequence and N rate on dry matter (DM) (kg ha^{-1}) at 3 weeks after planting and number of days to 50% tasselling of maize

Crop sequence (CS)	N Rate (NR) (kg ha^{-1})		Mean
	0	60	
DM at 3 weeks after planting			
Cassava	227	236	232
Pigeonpea	116	157	136
Mucuna-maize-mucuna	167	201	184
Cowpea-maize-cowpea	122	131	127
Maize-maize-maize	109	123	116
I. cylindrica fallow	61	87	74
Mean	134	156	
Number of days to 50% tasselling			
Cassava	59.3	57.8	58.5
Pigeonpea	62.0	61.8	61.9
Mucuna-maize-mucuna	60.3	58.5	59.4
Cowpea-maize-cowpea	63.0	60.8	61.9
Maize-maize-maize	63.5	61.8	62.6
I. cylindrica fallow	70.0	63.0	66.5
Mean	63.0	61.0	

Prob. F. (DM at 3 weeks after planting): CS = <0.0001; NR = 0.001; CS X NR = NS

SED (DM at 3 weeks after planting): CS = 9; NR = 5; CS X NR = 13

Prob. F. (Number of days to 50% tasselling): CS = <0.0001; NR = <0.0001; CS X NR = 0.001

SED (Number of days to 50% tasselling): CS = 0.6; NR = 0.4; CS X NR = 0.9

followed by maize with fertiliser. Across all crop sequences, application of mineral N fertiliser increased weed biomass by 31%. On the farmer managed plots, weed biomass associated with maize on plots previously cropped to cassava was about 40% of that found after the speargrass fallow (Figure 3).

5.3.5. Farmers' preference ranking for different crop rotations

Among the native farmers, cassava/maize rotation was ranked by both male and female farmers as the most preferred rotation while continuous cropping was ranked as the least preferred crop sequence (Table 6). However, whereas the males ranked cowpea/maize rotation as the second most preferred rotation, the female farmers ranked the pigeonpea/maize rotation as the second most preferred crop rotation.

The natives and the migrants differed in their preferential ranking mainly with respect to rotations involving long-duration crops such as pigeonpea and cassava. For instance, whereas natives ranked cassava/maize followed by pigeonpea/maize as the most important crop rotation, the migrants ranked cowpea/maize followed by cassava/maize as the most preferred rotation.

5.3.6. Relative profitability of the various crop rotations

Results of the economic analysis indicated that all the six crop sequences except the speargrass fallow resulted in a net positive revenue between US$34 and US$1827 corresponding to return on investments ranging from 10 to 254% during the first three cropping seasons (Table 7). The cassava cropping resulted in the highest return on investment whereas mucuna-maize-mucuna recorded the lowest return on investment.

In the fourth season, the residual effects of the previous crop sequence on maize yield resulted in additional return on investment of between 31-108% when N fertiliser was applied to the maize crop and between -6-167% when no N was applied to the maize crop. The highest return on investment was made by the rotation involving mucuna when N was applied to the maize crop succeeding mucuna while cassava rotation recorded the highest returns on investment when no N fertiliser was applied to the maize crop.

When the net revenues from the crops in the various crop sequences during the first three cropping seasons were added to those of the maize crop succeeding the various crop sequences in the fourth season, the returns on investment ranged from 29% with the continuous maize to 196% with cassava/maize rotation when N fertiliser was applied and from -22% with speargrass fallow/maize rotation to 235% with cassava/maize rotation when no N was applied (Table 8).

5.4. Discussion

5.4.1. Soil chemical properties

A comparison between the data in Table 1 and 2 suggests a reduction in organic carbon (-10% in the uppermost layer), nitrogen (-37%), K (-53%) after the experiments were carried out. While such data are consistent with the generally made claim about decline of soil fertility in African agro-ecosystems, we note that such rates of depletion are very high and more characteristic for the initial decline in soil organic matter after woodland clearance than for changes in (mining) agricultural practices (Zingore et al., 2005). Considering the very large increases in Ca (+27% in the uppermost layer) and Mg (+112%), we consider it likely that spatial variability of soil properties and variation due to the fact that samples were analysed in different batches are mainly responsible for the observed differences. It is therefore more important to note that the comparison between the different crop sequences did, apart from available P, not show significant differences in soil chemical properties in both the layers of 0-20 and 0-40 cm.

The absence of a significant effect of crop sequence on soil chemical properties provides evidence that the assertion that cassava depletes soil is not wholly true. The assertion that cassava causes soil degradation by nutrient depletion may be due to the fact that when cassava is grown on slopes, it is likely to cause more erosion than most other crops due to its wide spacing and slow initial canopy development (Putthacharoem et. al., 1998).

5.4.2. Dry matter production and Net N contribution to the system

Dry matter production by pigeonpea, cassava and mucuna-maize-mucuna systems were very high during the 3 growing seasons with high N accumulation while cowpea-maize-cowpea and maize-maize-maize system produced only small quantities of dry matter. Speargrass fallow produced a fairly high amount of dry matter and accumulated fairly large amount of N. Cassava and maize-maize-maize cropping removed substantial amount (70 and 40% respectively) of their DM from the system through crop harvest. In contrast, the grain legumes removed quite less (9, 31 and 35% for mucuna-maize-mucuna, pigeonpea and cowpea-maize-cowpea respectively) of their total DM from the system.

The highest net nitrogen contribution to the various systems was made by pigeonpea cropping followed by mucuna-maize-mucuna while cassava made the lowest net nitrogen contribution. Despite the high net N balance made by mucuna-maize-mucuna to the system, the collaborative farmers expressed their dissatisfaction with the use of mucuna as a soil fertility improvement legume since it does not provide immediate benefits such as food and cash income as cassava, cowpea and pigeonpea do. Mucuna is a herbaceous legume which has been tested intensively over the past decade both as a green manure and as a short duration fallow in West Africa where it has been shown to increase maize grain yield considerably (Carsky et al., 1998; Fofana et al., 2005). While the focus of scientists for introducing grain legumes into the farming system is to improve soil fertility for subsequent maize crop, the farmers' production objectives are for immediate food security need and cash income generation.

The strong net negative balance of 244 kg N ha^{-1} made by cassava is due to the large amounts of N removed in the stems that were not returned to the field as well as the large harvest of storage roots which was about 31 t ha^{-1}, being about more than twice the current national average of 12 t ha^{-1} (ISSER, 2005). In this study, the amount of N removed in the harvested storage roots was as much as 110 kg N ha^{-1}. This figure is however, less than that reported by Howeler and Cadavid (1983) but far more than that reported by Putthacharoen et al. (1998). Howeler (2002) reported that the amount of nutrients removed in the root harvest is highly dependent on growth rate and yield, which, in turn depends on climate, soil fertility condition and variety. However, if the stems of the cassava are returned to the system as happens on farmers' fields when the stems are not used as planting materials, then a considerable amount of the total N uptake could be returned to the soil since nutrient accumulation in the roots accounted for only 24% of the total N uptake (data not shown).

5.4.3. Effects of extensive cassava cropping on other macronutrients

While the data presented here suggest that the major beneficial effect of cassava on subsequent crops is due to the high N cycling properties of cassava litter, the very large initial effect of cassava on maize dry matter after 3 weeks could not be mimicked by N-addition. Our data could therefore point to the role of other nutrients. Our data are consistent with a hypothesis that cassava causes carry-over effects on initial growth and P-uptake of subsequent maize through mycorrhizal associations. Unfortunately, mycorrhizal associations were not studied. Beneficial effects of higher mycorrhizal inoculum at the start of the crop season have repeatedly been reported for maize (Miller, 2000; Osunde et al., 2003). Saïdou (2006) also suggested a major positive role for cassava on subsequent crops through stimulation of mycorrhizal associations.

Even though cassava, when grown on poor soils, acts as a scavenger crop and takes up relatively low amounts of N and P compared to other crops, its uptake (and hence removal through the harvest of storage roots) of K can be substantial (Howeler and Cadavid, 1983). The long-term effect of continuous rotation of cassava with maize could therefore be that K becomes a limiting nutrient, especially in soils where K availability is low – as is the case in these soils that contained 0.2 cmol K kg^{-1} soil. Long-term K balances are needed to further address this issue.

5.4.4. Effect of crop sequence and mineral N fertiliser application on maize yield

The higher maize grain yield without N application associated with cassava and mucuna-maize-mucuna plots could be attributed to the large amounts of N (157 and 142 kg ha^{-1} for cassava and mucuna respectively) in the biomass that were incorporated into the soil just before planting the maize (Table 3). The faster decomposition of the biomass and N release was better synchronised with maize demand than the slower release of N by the poorer quality materials like maize stover and speargrass.

Table 6. Preferential ranking of different crop rotations by native and migrant farmers in three communities (Asuoano, Beposo and Droboso) in Wenchi

Management practice	Ranking order							
	Natives				Migrants			
	Asuoano[a] (n = 10)	Beposo[b] (n = 5)	Droboso[c] (n = 7)	Average	Asuoano[d] (n = 6)	Beposo[d] (n = 6)	Droboso[e] (n = 5)	Average
a) Ranking by natives and migrants								
Cassava-maize	1	1	1	1	2	2	1	1.7
Pigeonpea-maize	2	5	2	3	4	4	4	4
Mucuna-maize-mucuna-maize	7	6	4	5.7	5	6	6	5.6
Groundnut-maize-groundnut-maize	4	3	3	3.3	3	3	3	3
Cowpea-maize-cowpea-maize	3	2	5	3.3	1	1	2	1.3
Maize-maize-maize-maize	8	7	6	7	7	7	7	7
Cowpea-cowpea-cowpea-maize	5	4	7	5.3	6	5	5	5.3
Speargrass dominated fallow-maize	6	8	8	7.3	8	8	8	8
b) Ranking by female and male natives								
	Females (n = 13	Males (n = 10)						
Cassava-maize	1	1						
Pigeonpea-maize	2	3						
Mucuna-maize-mucuna-maize	5	7						
Groundnut-maize-groundnut-maize	3	4						
Cowpea-maize-cowpea-maize	4	2						
Maize-maize-maize-maize	8	8						
Cowpea-cowpea-cowpea-maize	7	5						
Speargrass dominated fallow-maize	6	6						

[a]Consisted of 6 males and 4 females; [b]Consisted of 4 males and 1 female; [c]Consisted of 6 females and 1 male; [e]Dagarbas [d]Walas

Table 7. Estimated costs of production, gross revenue and returns on investment of (a) various crop sequences (b) maize grown after the sequences with N application to the maize and (c) maize grown after the sequences without N application to the maize

Crop sequence	Economic yield (t ha^{-1})	Total revenue (US$)	Cost of production (US$)			Total cost	Net revenue	Return on investment (%)
			Land	Input	Labour			
(a) Crops in the sequence								
[1]Cassava	31.000	2545	41.7	41.7	635	718	1827	254
[2]Pigeonpea	1.870	623	41.7	8.3	222	272	352	130
[3]Mucuna-maize-mucuna	2.016	365	41.7	41.7	247	331	34	10
[4]Cowpea-maize-cowpea	2.536 *(1,230)	1079	41.7	106.1	475	623	456	73
[5]Maize-maize-maize	3.287	595	41.7	36.1	386	464	456	28
[6]Speargrass fallow	0	0	41.7	0	0	42	-42	-100
(b) Maize after crop sequence with N application								
CS 1	2.738	496	13.9	104.2	190	308	188	61
CS 2	2.974	539	13.9	104.2	197	315	224	71
CS 3	4.194	759	13.9	104.2	246	364	395	108
CS 4	2.331	422	13.9	104.2	177	295	127	43
CS 5	2.126	385	13.9	104.2	175	294	91	31
CS 6	2.848	516	13.9	104.2	224	343	173	51
(c) Maize after crop sequence without N application								
CS 1	3.000	543	13.9	13.9	176	203	340	167
CS 2	2.423	439	13.9	13.9	166	193	246	127
CS 3	2.961	538	13.9	13.9	210	238	300	126
CS 4	1.772	303	13.9	13.9	155	183	120	66
CS 5	1.380	250	13.9	13.9	153	181	69	38
CS 6	1.048	190	13.9	13.9	174	201	-11	-6

[1]US\$82.1 t^{-1} fresh weight [2]US\$333.3 t^{-1} [3]US\$337.5 t^{-1} for cowpea and US\$181.1 t^{-1} for maize *Yield of maize

CS 1: Cassava; CS 2: Pigeonpea; CS 3: Mucuna-maize-mucuna; CS 4: Cowpea-maize-cowpea; CS 5: Maize-maize-maize; CS 6: Speargrass fallow

Table 8. Estimated costs of production, gross revenue and return on investment of six crop rotations when (a) N fertilizer is applied to the maize and (b) when no N fertiliser is applied to the maize

Crop rotation	Total revenue	Total cost of production	Net revenue	Return on investment (%)
(a) When N fertilizer is applied to the maize				
Cassava/maize	3041	1027	2014	196
Pigeonpea/maize	1162	586	576	98
Mucuna-maize-mucuna/maize	1125	695	430	62
Cowpea-maize-cowpea/maize	1501	918	583	64
Maize-maize-maize/maize	980	757	223	29
Speargrass/maize	516	384	132	34
(b) When no N fertilizer is applied to the maize				
Cassava/maize	3088	922	2167	235
Pigeonpea/maize	1062	465	597	129
Mucuna-maize-mucuna/maize	903	568	335	59
Cowpea-maize-cowpea/maize	1382	806	576	71
Maize-maize-maize/maize	845	645	201	31
Speargrass/maize	190	243	-53	-22

The lack of response of maize to the applied N on the cassava plot could however be attributed to the large amount of N released during the decomposition of the cassava biomass which may have reduced the use efficiency of the added N fertiliser. Kumar and Goh (2003) reported that when good quality residues are added to a soil, a large amount of N is released which reduce the efficiency of use of added fertilisers. High-quality organic residues with low

C:N ratios are known to have nitrogen release pattern similar to that of mineral fertilisers (Palm et al., 2001). It is argued therefore that since interaction between the same element or ion are unlikely, high quality organic residues of narrow C:N ratios which decompose and mineralise N rapidly are unlikely to cause strong interactions with mineral fertilisers (Giller, 2002). Since the soils were poor in organic matter and have low capacity to retain nutrients most of the N applied became prone to losses through leaching and erosion. The response of maize on mucuna plots to the applied N could be related to benefits from the incorporated residues resulting in better conservation and use of the applied N and moisture (Tian et al., 2000).

Although the large quantity of speargrass biomass (12.7 t ha^{-1}) incorporated into the soil potentially contained a large amount (171 kg ha^{-1}) of N, the high C:N ratio of speargrass (C:N = 37) resulted in immobilisation of soil N for the decomposition of the material resulting in poor maize grain yield when no N was applied. Poor-quality organic residues, with high C:N ratio, provide an abundant supply of C for microbial growth leading to immobilisation of soil N in the microbial biomass (Recous et al., 1995; Sakara et al., 2000). The detrimental effect of applying a large quantity of speargrass as fresh biomass on yield of sweet potato has been reported elsewhere (Kamara and Lahai, 1997) and has been attributed to high C:N ratio and phytotoxicity of speargrass.

The yield obtained in this experiment under the various crop sequences is more related to the quantity and quality of biomass incorporated into the soil just before the maize test crop was planted rather than the net nitrogen contribution to the system. While materials of poorer quality such as those of maize stover and speargrass released their N slowly at rates and levels not sufficient to meet the demand of the growing maize crop, materials of relatively good quality such as those of cassava, pigeonpea and mucuna may have released sufficient N to meet the demand of the growing maize crop leading to relatively higher maize grain yield even when N fertiliser was not applied. Thus the response of maize to mineral fertiliser application was relatively stronger on plots previously under speargrass and maize-maize-maize where large amounts of poor quality materials were incorporated into the soil.

Maize grain yields after the various crop sequences were generally smaller on farmer-managed plots compared to those of researcher-managed plots. These differences could be attributed to differences in the management of biomass of pruning and crop residues in the field before planting the maize test crop. For instance while on the researcher-managed plots, crop residues and biomass of cassava, pigeonpea, speargrass, maize and mucuna were incorporated into the soil immediately after harvest, on the farmer-managed plots they were either burnt or incorporated into the soil after leaving them to dry in the sun for one week. The effects of biomass pruning and crop residue management on decomposition and subsequently N recovery by crops have been discussed extensively by Mafongoya et al. (1998).

5.4.5. Effect of crop sequence and N application on weed biomass

Weed biomass was highest in the speargrass fallow and in the mineral N fertiliser treatment and least in the cassava system compared with the other treatments (Figure 2). The high weed biomass in the speargrass fallow treatment could be attributed to rhizomes of the speargrass that were already in the soil before the maize crop was planted, whereas the low weed biomass in the cassava system could be due to suppression by the dense-shading cassava canopy of speargrass rhizomes that were originally in the soil before the land was cleared. In agricultural systems, shade suppresses weeds growing on the site and interrupts continuous re-seeding of the field (de Rouw, 1995). Improved N availability to weeds as a result of fertiliser application to maize was responsible for the high weed biomass that was associated with the fertilised maize crop.

5.4.6. Farmers' preference ranking for the different crop rotations

Although mucuna-maize-mucuna rotation improved maize grain yield, it was not a preferred option for most of the farmers (both natives and migrants). Incorporating mucuna residues into the soil markedly improves maize yield but it requires substantial labour (24 persons day ha^{-1}) (Table 9) and its cultivation does not provide farmers with immediate cash or food. These factors strongly affect farmers' acceptance of green manuring, particularly of mucuna as an option for replenishing soil fertility in such farming system dominated by maize monocropping.

Both native and migrant farmers ranked speargrass fallow/maize rotation as the least preferred option (Table 6) due to the consistently poor yield observed in this system both on farmer-managed and researcher-managed fields. Although incorporating the fresh biomass into the soil with supplementary N considerably increased maize yield, this requires substantial amount of labour (Table 9), when tractors are not available. High costs of chemical fertilisers and lack of access to credit limit fertiliser use among farmers.

The migrant farmers in general and the Walas in particular preferred the cowpea/maize rotation over both cassava/maize and pigeonpea/maize rotations although they acknowledge the superiority of the latter two over the former in terms of soil fertility improvements and maize grain yield. According to the Walas, the markets for cassava and pigeonpea are not always readily available and return on investment too slow. In addition they are afraid that when they

Table 9. Estimated labour requirements for incorporating residues of different plant materials under different crop sequences into the soil, estimated labour charge ha $^{-1}$ based on daily labour rate and person days ha $^{-1}$ and prevailing labour rate ha $^{-1}$ based on contract labour in Wenchi

Crop sequence	Person days/ha	[b]Charge/ha (¢)	Prevailing labour rate in the communities (¢)/ha
Cassava	14	280,000	300,000
Pigeonpea	17	340,000	NA
Mucuna	24	480,000	NA
Maize	14	280,000	300,000
Cowpea	13	260,000	300,000
Speargrass fallow	34[a]	400,000	NA
SE	0.58		
P>F	0.001		

* Tractor is used at ¢400,000/ha

[b]Based on charge per day is ¢20,000

invest in the soil, they would not be allowed to reap the full benefits. Hence they prefer rotations which involve the growing of short-duration crops like maize and cowpea which have ready market and quick return on investment.

While both native male and female farmers prefer the cassava/maize rotation over all the others, they differ in their preference with respect to rotations involving the two most important legumes, cowpea and pigeonpea. The women prefer cassava/maize and pigeonpea/maize rotations due to the role cassava and pigeonpea play in food security. Besides, most female farmers feel that since the cultivation of cowpea involves the use of external inputs such as insecticides and herbicides, they cannot raise the financial capital required to purchase these inputs (Adjei-Nsiah et al., 2006). As a result most women prefer rotations involving crops like pigeonpea and cassava which require minimal use of external inputs such as pesticides and fertilisers. Pigeonpea and cassava are also preferred by the women because of their relatively lower labour demand. Berry (1993: 187) attributes women's preference for cassava cultivation over other crops to its flexible labour requirement.

5.4.7. Profitability of the various crop sequences and rotations

Although the mucuna-maize-mucuna/maize rotation gave both the highest net revenue and return on investments during the fourth season when N fertiliser was applied to the maize, the low net revenue and return on investment during the first three seasons eroded these gains. The combined net revenues from both the first three seasons and the fourth season resulted in only 62% return on investment (when N was applied to the maize) for the two year period which is far lower than those made by cassava/maize, pigeonpea/maize and cowpea/maize/cowpea/maize rotations which were 196, 100 and 64% respectively (Table 8). Considering the current interest rate of 25-30% in the formal sector, and sometimes up to 100% in the informal sector, it will only be profitable for farmers to adopt mucuna/maize rotation as a soil fertility management strategy when they obtain credit from the formal sector. Thus, farmers' reluctance to accept mucuna green manuring as a soil fertility management strategy could be justified considering the fact that no return is made during the period that the mucuna is growing in the field despite investments made in labour and seed inputs.

Except for speargrass fallow, where fertiliser application resulted in high return on investment compared to the unfertilised plots, fertiliser application generally resulted in a lower return on investment. This means that the yield increase obtained as a result of fertiliser application could not compensate for the investment made in the application. This may be either due to the low price of maize grains or high cost of fertiliser or both. Gerner et al. (1995) demonstrated that an increase in the price of fertiliser without a corresponding increase in the price of the produce reduces profitability of using fertiliser.

Cassava/maize rotation resulted in the highest return on investment both when N fertiliser is applied to the maize crop or not for the 2 year period. This was due to the high cassava storage root yield obtained in this experiment. However, migrant and landless farmers are likely to adopt cowpea/maize rotation instead of cassava/maize rotation, partly due to difficulty farmers sometimes encounter in marketing their cassava. When there is no readily available market, farmers have to leave the crop in the field until the time that buyers come to buy, a situation which is not conducive for farmers who rent land. Due to the flexibility in its labour requirement (Berry, 1993) and its low external input demand, cassava is the most preferred crop for women farmers (Table 6). Although speargrass fallow gave a negative return on investment during the first three seasons, it made a return on investment of 51% during the forth season when fertiliser was applied to the succeeding maize crop, which was higher than that made by cowpea-maize-cowpea (43%) and maize-maize-maize (31%) (Table 7).

If a good decision is to be made based on the return on investment and current interest rate of between 25-30% in the formal sector and sometimes up to 100% in the informal sector, and assuming that marketing for produce is not a constraint, then it can be recommended to farmers to adopt cassava/maize, pigeonpea/maize and cowpea/maize/cowpea/maize rotations.

5.5. Conclusion

The study shows how farmers adapt their rotational sequences to meet their immediate food security and cash needs while maintaining the fertility of their soils. Growing cassava, pigeonpea, cowpea and mucuna and incorporating their residues, particularly leaf litter and green leafy biomass where available can serve as a means of allowing farmers with limited access to finance to improve the fertility of their soils, control weeds and give an initial N boost to the succeeding maize crop.

The beneficial effect of cassava on maize grain yield was mainly due to the relatively high amount of N that was returned to the soil through leaf litter and green leafy biomass of the cassava plant. This is, however, recycled N, since cassava does not have the capacity to fix N like legumes. It is also worthy to note that the cassava removed the largest amount of N from the system and yet performance of maize after cassava was comparable with that of maize on plots previously cropped to mucuna and pigeonpea which are N_2-fixing plants. The soil on which this study was carried out was quite fertile as evidenced by the high storage root yield as well as the high net negative N balance of 244 kg ha^{-1}. We cannot, therefore, exclude the possibility that on poor soils, maize may perform poorly after cassava harvest.

The highest return on investment made by cassava/maize rotation in this study was due to the high tuber yield obtained and therefore it is unlikely that we may have similar result if the experiment is performed on less fertile soil where the yield of cassava is likely to be lower than the one obtained in this study. In terms of profitability, cassava / maize rotation, followed by pigeonpea / maize rotation appears to be the best option for farmers. However, evaluation of the different rotational systems by the different groups of farmers indicates that the choice of a particular rotation is strongly related to access to resources (e.g. land, labour, and cash) and circumstance of the farmer.

The study thus suggests that in developing soil fertility management technology for a farming community like Wenchi where the population is very heterogeneous, it may be desirable to modify research efforts by deliberately targeting technologies for different categories of farmers depending on their circumstances and resources available to each category of farmers.

References

Adjei-Nsiah, S., Leeuwis C., Giller K.E., Sakyi-Dawson O., Cobbina J., Kuyper T.W., Abekoe M. K. and Van Der Werf W., 2004. Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: implication for interdisciplinary action research. NJAS-Wageningen Journal of Life Sciences, 52: 331-348.

Adjei-Nsiah, S., Leeuwis, C., Sakyi-Dawson, O., Giller, K.E., and Kuyper, T.W., 2006. Exploring diversity among farmers for orienting interdisciplinary action research on cropping system management in Wenchi, Ghana: the significance of time horizons. International Journal of Agricultural Sustainability (accepted).

Asiamah, R.D., Adjei-Gyapong T., Yeboah E., Fenning J.O., Apontuah E.O. and Gaisie E., 2000. Report on Soil Characterisation and Evaluation at four Primary Cassava Multiplication Sites (Mampong, Wenchi, Asuansi and Kpeve) in Ghana. Technical Report No 200, Soil Research Institute, Kumasi, 91 pp.

Bank of Ghana (2005) Periodic Economic Reports: Half year Economic Review 2005 (Provisional Data) www.bog.gov.gh accessed on 2nd June, 2006.

Berry, S., 1993. No Condition is Permanent-The sociological Dynamics of Agrarian Change in sub-Saharan Africa. The University of Wisconsin Press, Madison.

Budidarsono, S. Tomich, T.P., Lusiana, B., and van Noordwijk, M., 1998. Profitability Assessment of Transmigration Land Use System, Degraded to *Imperata cylindrica* Grassland. Southeast Asia Policy Research Working Paper, No. 6, Bogor, Indonesia, 82 pp.

Carsky, R.J., Tarawali S.A., Becker M., Chikoye D., Tian G., Sanginga N., 1998. Mucuna-herbaceous cover legume with potential for multiple uses. Resource and Crop Management Research Monograph 25. IITA, Ibadan, Nigeria.

Crews, T.E., Peoples, M.B., 2004. Legume versus fertiliser sources of nitrogen: ecological trade-offs and human needs. Agriculture, Ecosystems and Environment, 102: 279-297.

De Rouw, A., 1995. The fallow period as a weed-break in shifting cultivation (tropical forests). Agriculture, Ecosystems and Environment, 54: 31-43.

Fofana, B., Tamélokpo A., Wopereis M.C.S., Breman H., Dzotsi K., and Carsky R.J., 2005. Nitrogen use efficiency by maize as affected by a mucuna short fallow and P application in the coastal savanna of West Africa. Nutrient Cycling in Agro-ecosystems, 71: 227-237.

Gerner, H., Asante, E.O., Owusu Benoah, E. and Marfo, K., 1995. Ghana fertilizer privatization scheme: Private Sector Roles and Public Sector responsibilities in meeting needs of farmers. IFDC-Africa, Lome, Togo.

Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems, 2nd edn. CAB International, Wallingford, UK.

Giller, K.E., 2002. Targeting management of organic resources and mineral fertilisers: Can we match scientists' fantasies with farmers' realities? In: B. Vanlauwe, J. Diels, N. Sanginga, and R. Merckx (Eds.), Integrated Plant Nutrient Management in Sub-Saharan Africa. CAB International, Wallingford, UK. Pp 155-170.

Giller, K.E. and Cadisch, G. 1995. Future benefits from biological nitrogen fixation: an ecological approach to agriculture. Plant and Soil, 174: 255-277.

Hendershott, C.H. 1972. A literature Review and Research Recommendations on Cassava, *Manihot esculenta*, Crantz. Unpublished paper. University of Georgia, Athens, Georgia. Cited in Nweke, F.I., Spencer, D.S.C. and Lynam, J.K, 2002. The Cassava Transformation, Africa's Best-Kept Secret. Michigan State University Press, East Lansing.

Howeler, R.H., 2001. Long-term effect of cassava cultivation on soil productivity. Field Crops Research, 26: 1-18.

Howeler, R.H., 2002. Cassava mineral nutrition and fertilization. In: Hillocks, R.J., Thresh, M.J., Bellotti, A.C. (Eds), Cassava: Biology, Production and Utilization. CAB International, Wallingford, pp.115-147.

Howeler, R.H., Cadavid, L. F. 1983. Accumulation and distribution of dry matter and nutrients during a 12-month growth cycle of cassava. Field Crops Research, 7: 123-139.

ISSER, 2005. The state of the Ghanaian economy in 2004. Institute of Social, Statistical and Economic Ressearch, University of Ghana, Legon.

Kamara, A.Y. and Lahai, M.T., 1997. Differential response of sweet potato (Ipomoea batata) to green manuring with elephantgrass (*Pennisetum purpureum*) and speargrass (*Imperata cylindrica*) on a ferralitic soil in Sierra Leone. Der Tropenlandwirt, Beiträge zur tropischen Landwirtschaft und Verterinärmedizin, 98: 229-235.

Kumar, K. and Goh, K.M., 2003. Nitrogen release from crop residues and organic amendments as affected by biochemical composition. Communications in Soil Science and Plant Analysis, 34: 2442-2460.

Mafongoya P.L., Giller K.E. and Palm, C.A. 1998. Decomposition and nitrogen release pattern of tree prunings and litter. Agroforestry Systems, 38: 77-97.

Miller, M.H. 2000. Arbuscular mycorrhizae and the phosphorus nutrition of maize: a review of Guelph studies. Canadian Jurnal of Plant Science, 80: 47-52.

Nweke F.I., Spencer D.S.C. and Lynam J.K., 2002. The Cassava Transformation. Africa's Best-Kept Secret. Mitchigan State University Press, East Lansing.

Osunde, A.O., Bala, A., Gwam, M.S., Tsado, P.A., Sanginga, N. and Okugun, J.A., 2003. Residual benefits of promiscuous soybean to maize (*Zea mays* L.) grown on farmers' fields around Minna in the southern Guinea savanna zone. Agriculture, Ecosystems and Environment, 100: 209-220.

Palm, C.A., Giller, K.E., Mafongoya P.L. and Swift M.J., 2001. Management of organic matter in the tropics: translating theory into practice. Nutrient cycling in Agro-ecosystems, 61: 63-75

Peoples, M.B. and Crasswell, E.T., 1992. Biological nitrogen fixation: Investment, expectations and actual contributions to agriculture. Plant and Soil, 141: 13-39.

Peoples, M.B., Herridge, D.F. and Ladha, J.K., 1995. Biological nitrogen fixation: an efficient source of nitrogen for sustainable agricultural production. Plant and Soil, 174: 3-28.

Putthacharoen S., Howeler R.H., Jantawat S. and Vichukit V., 1998. Nutrient uptake and soil erosion losses in a Psamment in eastern Thailand. Field Crops Research, 57: 113-126

Recous S., Robin D., Darwis D. and Mary B. 1995. Soil inorganic N availability effect on maize residue decomposition. Soil Biology and Biochemistry, 27: 1529-1538.

Saïdou, A. 2006. Converging Strategies by Farmers and Scientists to Improve Soil Fertility and Enhance Crop Production in Benin. PhD thesis, Wageningen University.

Saïdou, A., Kuyper T.W., Kossou D.K., Tossou R. and Richards, P., 2004. Sustainable soil fertility management in Benin: learning from farmers. NJAS-Wageningen Journal of Life Sciences, 52: 349-469.

Sakala W.D., Cadisch G. and Giller, K.E., 2000. Interactions between residues of maize and pigeonpea and mineral N fertilisers during decomposition and N mineralization. Soil Biology and Biochemistry, 32: 679-688.

SAS 1996. SAS User's Guide: Statistics. SAS Institute, Cary, NC.

Sitompul, M., Setijono, S., van der Heide, J. and van Noordwijk, M., 1992. Crop yields and sustainability of cassava-based cropping systems on an ultisol in Lampung. Agrivita, 15: 19-28.

Tian, G., Kolawole, G.O., Kang, B.T. and Kirchhof, G., 2000. Nitrogen fertilizer replacement indexes of legume cover crops in the derived savanna of West Africa. Plant and Soil, 224: 287-296.

Zingore, S., Manyame, C., Nyamugafata, P. and Giller, K.E., 2005. Long-term changes in organic matter of woodland soils cleared for arable cropping in Zimbabwe. European Journal of Soil Science, 56: 727-736.

CHAPTER 6

Negotiation and experimentation towards alternative land tenure arrangements among native and migrant farmers in Wenchi. The significance of ambiguity and self-organized institutional innovation

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Abstract

This study reports on action research efforts that were aimed at developing institutional arrangements beneficial for soil fertility improvement. Three stages of action research are described and analyzed. We initially began by bringing stakeholders together in a platform to engage in a collaborative design of new arrangements. However, this effort was stranded mainly because conditions conducive for learning and negotiation were lacking. We then proceeded to support experimentation with alternative arrangements initiated by individual landowners and migrant farmers. The implementation of these arrangements too ran into difficulties due to intra-family dynamics and ambiguities regarding land tenure. Further investigations to find out how ambiguities could be tackled revealed that the local actors themselves had taken initiatives towards developing institutional innovations to reduce ambiguities. However, there is still considerable scope for further development of these self-organized innovations. The article ends with a reflection on inter-disciplinary action research, where it is argued that making ‘mistakes’ is an inherent and necessary characteristic in action research that aims to address complex social issues.

6.1. Introduction

In a developing economy such as Ghana, access to land and natural resources is important for improving the livelihoods of poorer groups. Farmers’ livelihood decisions with respect to cropping strategies and labor input are strongly influenced by land tenure arrangements (DFID, 2000). Several authors (Gavian and Ehui, 1999; Gavian and Fafchamps, 1996; Fraser, 2004) argue that contractual arrangements such as land renting and sharecropping reduce incentives to invest in soil fertility management due to tenure insecurity. Gavian and Fafchamps (1996) reported that tenure insecurity incites farmers to divert soil-enhancing resources to more secure fields whenever possible.

In an earlier study (Adjei-Nsiah et al., 2004), we also found an association between tenure insecurity among migrant farmers especially, and limited attention for regeneration of soil fertility. We showed that native farmers who own land tend to use long-term rotational strategies such as rotations with cassava and pigeonpea to improve their soils. In contrast, migrants appear to depend mostly on short-term rental or sharecropping arrangements, which prevents them from using such long-term rotations. Instead, they rely more on rotations with short duration crops such as cowpea and groundnut to enhance soil fertility. At the same time, however, migrants tend to continuously crop the same piece of land to maize for two years in both the major and minor seasons in order to get the maximum from the land, thus mining the soil of nutrients. Due to this, the landowning natives often accuse the migrants of degrading their lands, which in turn makes them reluctant to rent land to migrants beyond two years. The migrants cite tenure insecurity and high cost of land rent as reasons for not investing in soil fertility regeneration. Thus, it appears that there is a widespread lack of trust between the migrants and the natives. The natives do not trust that when they rent land to migrants for a longer period, they will take good care of it. The migrants on the other hand are afraid that when they invest in soil fertility, they will not be allowed to reap the full benefit.

On the basis of these findings, we suggested that our action research efforts should not remain only in the sphere of developing better technologies and management practices together with farmers. We concluded that, in order to deal with this social dilemma situation, we needed to intensify efforts in the social realm and engage in the joint design of institutions through negotiation of, and experimentation with, new kinds of contractual and / or land tenure arrangements (Adjei-Nsiah et al., 2004). This idea of working on institutional arrangements is in line with recent insights in innovation studies which suggest that social conditions needed for the uptake of technology should be regarded as an integral component of an innovation, and not as an 'external' factor influencing adoption of innovations (as e.g. in Rogers, 1983). Innovations are increasingly seen as consisting of a balanced whole of 'hardware' (technology), 'software' (human mindsets and modes of thinking) and 'orgware' (new rules, market arrangements, forms of organization, etc.) (Smits, 2002; Geels, 2002). At the same time, the idea to work on institutional arrangements can be seen as relevant addition to well-known methodological strategies to making agricultural research more relevant to resource-poor farmers, most notably Farming Systems Research (FSR; see Collinson, 2000) and Participatory Technology Development (PTD, see Van Veldhuizen et al., 1997). In both FSR and PTD the tendency has been to work on the design of new and/or more appropriate *technologies* rather than on social conditions.

This article reports on action research efforts aimed at developing 'orgware' beneficial to soil fertility improvement. The focus hereby was on the design of more favourable land tenure arrangements among natives and migrants in Wenchi. In addition to answering the question of what alternative tenure arrangements might ameliorate the tensions and social dilemma between migrants and natives, this paper also seeks to draw lessons on action research in the social realm. In this line, we discuss factors that led to the failure of the attempts that were made to negotiate and experiment with new/alternative forms of arrangements.

6.2. Land tenure in Ghana

As a background to the research, we highlight some relevant aspects and issues regarding land tenure in Ghana, whereby we move from more general characteristics to specific circumstances in our research area.

6.2.1. The continued dominance of customary institutions

In Ghana land is an index of political power in the country's ethnic communities (Addo-Fening, 1972) and struggles over land are not just struggles over an economically valuable resource but rather they constitute arenas of simultaneous struggle over wealth, power and knowledge (Berry, 2002). Often conflicts over access to a particular tract of land are at the same time related to struggle over who has the authority to decide how the land is to be allocated and used and on what basis (Berry, 2002).

Traditionally, control over access to, and use of, land in the country lies either in the lineage or the stools rather than individual families (Fred-Mensah, 1999). Among the Akans, the chief is the custodian of the land while among the non-Akan people, land is administered by the lineage heads. Families have gained rights and use of land by their residence and political allegiance to the stools. Individuals, on the basis of their membership of a family or a lineage group, also have usufruct rights over communal, family or lineage land. Marriage is another important institution through which in-married spouses gain secure access to land.

Despite the many attempts that have been made to integrate all forms of tenure into single statutory and common law framework since 1986, land tenure in Ghana is still largely regulated by customary institutions (Crook, 2005). In Ghana, initial rights to land are generally established through clearing the bush and first occupation. The individual who first cleared the land and his descendants retain a pre-eminent right over it and can grant temporal or extended right to others. Migrant farmers and/or those who do not have sufficient access to land usually gain access to land through various forms of tenancy arrangements such as renting, sharecropping and *taungya*.

However, rules governing access to land are ambiguous and people's claims to land are closely linked to membership in social network and participation in formal and informal politics (Berry, 1993). The social relations between tenants and landowners are of significant importance in terms of ensuring continuous access to land and arrangements. To obtain and maintain access to valuable resource like land, people invest in social relationships by contributing items such as food, drinks, gifts and ritual offerings during ceremonies such as marriage, funerals and festivals. In addition to ceremonies, farmers also invest in social relationships by contributing to community projects and organizations such as home-town improvement unions, religious associations and self-help groups (Berry, 1993).

6.2.2. Land tenure evolution in Wenchi district

Wenchi district is characterized by the presence of different ethnic groups, the majority of which are migrant farmers from the northern part of Ghana. The district has historically attracted a lot of farmers from the northern part of Ghana in search of suitable place to farm because of its abundant natural resources, particularly land in the past. Wenchi, the district capital is strategically located because it is the first major town encountered when one is traveling from Nandom or Wa (the original homes of most of these migrants) to Kumasi, the second largest city in Ghana. Wenchi is also close to Techiman, one of the fast-growing marketing centers in the West Africa sub-region where there is strong demand for high-valued food crops like maize, yam and groundnut. Originally, migrant farmers gained access to farmlands by presenting drinks and a salutation fee to the chiefs who then allocated land to them from which they were allowed to clear as much land as they could (Amanor, 1993). Later, in the early 1940 when more people moved into Wenchi in search of fertile land for the cultivation of crops such as cocoa, the traditional council issued land to migrants on the basis of *Abusa* or collected annual tributes (Amanor (1993). In Wenchi, an *Abusahene* (Chief responsible for managing natural resources in the traditional area) was created to manage the hiring of stool land to migrants. In the early 1960's the central government banned the traditional council from raising revenues in tributes and instead introduced an annual fee (Amanor, 1993). Once the annual fee was paid, the migrant could clear as much land as wished in the area allowed. Currently this fee stands at ¢200,000.00 (US$22) annually or an equivalent of 1 bag of 100 kg maize.

As the population of the migrants increased, migrants began to enter into various forms of land tenure contracts with the natives. These contracts evolved from a system whereby migrants obtained land in return for services rendered, to systems such as sharecropping and rent. In the period when land was in abundance and the population was low, landowners often gave their land out for sharecropping. However, as the monetary value of the land increased, most landowners began to rent out their land to migrants instead of entering into share contract. This monetary value has increased on one hand by the circumstance that families and individuals owning land have become more interested in cash along with the greater role of money in the economy at large, and on the other hand by the increasing scarcity of land in view of population increase and migration of farmers from the Upper West region coupled with commercialization of agriculture. For instance people need money to pay for emergency expenditures such as medical bills, funeral expenses, court cases and shelter.

6.2.3. Tensions between natives and migrants in the research area

The study took place in three nearby communities in Wenchi district which are located about 5-7 km away from Wenchi along the Wenchi-Techiman road. The farmers in these communities have been involved in action research trials in soil fertility management since 2003, after a diagnostic study revealed the existence of intriguing practices and beliefs regarding the role of cassava in soil fertility management (Adjei-Nsiah et al., 2004). The communities which are made up of natives (80%) and migrants (20%) have a total population of about 3750, majority of which are farmers. The natives who are the landowners are Akan speaking Bonos while the migrants are made up of four ethnic groups namely the Walas (50%), the Dagarbas (30%), the Lobis (10%) and the Mossi (10%). A further exploration of diversity in the research area (Adjei-Nsiah et al., 2006a) revealed that the various ethnic groups differ with respect to history and context of migration, duration of stay and the nature and quality of relationship with the local communities. For instance, while the Mossi, Lobis and the Dagarbas migrated into the communities between the 1940s and 60s, the Walas started migrating into the communities in the early 1990s. And while the earlier categories of migrants have developed long-standing relations with the natives and regard their stay as permanent, the Walas tend to view their stay in the community as temporal and repatriate a considerable part of their income to their home of origin. In comparison with the other migrant groups, the Walas tend to have relatively large farming enterprises and seem to be relatively successful in economic terms (Adjei-Nsiah et al., 2006a).

In the research area, tensions around land tenure have arisen in particular between the native Bonos and the Walas. As mentioned in the introduction, the Bonos tend to accuse Walas of degrading the soil on land rented out to them, while the Walas claim that the high rents and advance payments demanded by the Bonos prevent them from hiring land for longer periods and leave them no choice but to exploit the land to recoup the money invested. In addition, they complain that landowners will not allow them to reap the benefits of investments made in soil fertility on land that is rented for shorter periods (Adjei-Nsiah et al., 2004). Also in other areas tensions have risen between the natives and the Walas. The natives dislike that the Walas are putting up thatch roofed houses in the community which – according to the natives– makes the community look ugly, while at the same time the Walas repatriate income from their farming activities back home to reinvest. The natives have on several occasions threatened the Walas to no longer allocate plots to them to put up their own houses in the community. In some occasions, Walas have been dragged to court or brought before the village committee by the natives with the least provocation, often resulting in fines being imposed on the Walas. Some of the migrants have had their sheep and goats poisoned by some of the natives after straying through their fields. These hostilities by the natives tend to be interpreted by the migrants as jealousy on their hard work and success in their farming activities. In short, the relations between Bonos and Walas are tense and unhealthy and go along with accusations and stigmatization from both sides (see also Adjei-Nsiah et al., 2006a).

6.3. Action research methodology

Due to the social dynamics occurring in and around the action research, efforts to work towards more favourable land tenure arrangements had to be re-oriented several times. In view of these changes, the research journey can be seen to have three main stages. Each stage is characterized by specific objectives, approaches and research methods. More details about these are provided in the sections: stages 1, 2 and 3. In stage 1, we tried to use multi-stakeholder platforms as forums for negotiating alternative tenure arrangements. In stage 2, we monitored experimentation with alternative land tenure arrangement initiated by two pairs of landowners and tenant farmers. In the stage 3, we made investigations into institutional problems associated with land tenure and emerging institutions to deal with these problems. All field research was carried out by the first author. Reference to his activities in the description of the 3 stages will be in the first person from hereon.

6.3.1. Stage 1: Discussing land tenure in multi-stakeholder platforms

Research approach and methodology in stage 1

From the start of the collaboration, on-farm experimentation with farmers on different cropping systems and rotation strategies was an important component of the action research, and this remained so throughout the research period. These experiments took place together with 3 mixed groups of farmers with each group consisting of between 11-16 farmers. Altogether the experimental group consisted of 18 migrants (2 Lobis, 5 Dagarbas and 11 Walas) and 21 native farmers plus the local agricultural extension agent. Some of the native farmers were also opinion leaders, unit committee members (which is the lowest rung in the decentralized formal administrative structure of the government of Ghana) and sub-chiefs in the communities. Only one migrant was a member of the unit committee representing the migrants. This group carried out all experimental activities and served at the same time as a platform to discuss the outcomes of the research, including issues regarding land tenure. The group (from now on the ‘experimental platform’) met in the field on a bi-weekly to monthly basis.

In addition to this experimental platform, a second platform was created from the outset with the prime purpose of ensuring that research findings would not remain within the group of participating farmers. This second platform included various stakeholders in the agricultural sector in the district, and met once in every three months to discuss the activities of the action research program being carried out with the farmers. These stakeholders included chiefs, sub-chiefs from the three communities, agricultural extension agents, farmers, representatives of NGOs and farmer-based organizations and opinion leaders. Officially this higher-level platform consisted of 25 members, but as meetings took place in the community there were often more people attending, including farmers from the experimental platform. In practice, this meant that attendance was normally between 40 and 60 people. I asked a local senior official associated with the Wenchi District Assembly to facilitate and chair the first meeting of the platform and he was asked by the group to continue his efforts in subsequent meetings.

During the platform meetings, I acted as a resource person and stand-in facilitator. At the same time, I acted as a 'participant observer' who monitored and documented the dynamics in the platforms for PhD research purposes. When the initial experiments and subsequent discussions on the outcomes in the experimental group revealed the existence of tensions on land tenure, I decided to try and use the already established platforms in order to discuss, negotiate and design alternative land tenure arrangements. This strategy was informed by a popular body of literature which suggests that multi-stakeholder platforms can contribute much to resolving complex problems and conflicts regarding natural resources (Ostrom, 1990; Röling and Jiggins, 1998; Maarleveld & Dangbégnon, 1999; Steins and Edwards, 1999). Essentially, the idea behind this is that such platforms can contribute to conflict resolution by providing a space for exchange of perspectives, dialogue and learning (Bawden, 1994; Pretty and Chambers, 1994; Berkes and Folke, 1998; Röling and Wagemakers, 1998), which in turn might lead to the identification of common objectives, understandings and creative solutions.

Results in stage 1: The failure to sustain a constructive dialogue

During the first year of experimentation, positive effects of rotations with mucuna, pigeonpea and cassava became evident (Adjei-Nsiah et al., 2006b). However, most of the migrants argued that the prevailing land tenure arrangements in the community would not allow them to apply these practices to improve the productivity of their land. From that period onwards, several suggestions were made by both migrants and natives in the experimental group about possible alternative land tenure arrangements that would encourage migrants also to apply these management strategies. Most of the suggestions made by the migrants required that, to enable them to use cassava and pigeonpea to improve the soil, rent for the period that these crops would be on the plot should be reduced to the minimum if not struck off altogether. Most of the landowners, however, were of the view that even if the land is given to migrants at zero or reduced rent to enable them to cultivate cassava or pigeonpea to improve the soil, they would still use the land to grow maize since income from pigeonpea and cassava is poor compared with maize. Hence, they argued that the type of arrangement proposed by migrants would only work if it went along with clear agreements about the crops to be grown, including sanctions in case of violation. Even if disagreement remained, discussions in the experimental group were held in a relaxed and peaceful atmosphere initially and members on this platform expressed their opinions freely. These constructive discussions ended, however, some time after the issue of land tenure had become an issue for discussion in the higher-level platform.

As the higher-level platform was regularly informed about the results of experiments as well as on progress in the experimental platform, the issue of land tenure became an issue for discussion there too. In fact, it soon became the dominant topic for debate. In contrast to the open atmosphere in the experimental platform, however, communication in the higher platform soon took the form of accusations and counter-accusations. Native leaders started to blame the migrants for the occurrence of soil degradation, and migrants responded by uttering grievances regarding limited land security. On several occasions tensions rose high, and I was not successful in redressing this pattern of exchange. After the fourth meeting of the higher-level platform, the leader of the Walas came to see me and requested that the discussions on the land tenure be discontinued. His argument was that if the discussions continued, the community leaders would design rules to regulate their access to land, and if they were not able to follow those rules it would worsen their already sour relationships with the native community. I agreed to do this in order not to jeopardize my other work and relations with the various communities.

Analysis and discussion of findings in stage 1

The fact that discussions on land tenure had to be aborted in the platforms can be attributed to several factors. In retrospect, it has probably been a major strategic fault to shift the discussions on land tenure from the experimental platform to the higher-level platform at an early stage in the process. For several reasons this platform was far less suited for discussing such a sensitive issue. People in the platform lacked the collaborative experience of joint experimentation accompanied with intensive informal interaction in the field. Hence, they did not know each other well at a personal level, and had little common experience other than having gone through previous conflicts that had caused the relations between Walas and Bonos to be damaged. As Steins and Edwards (1999) argue, productive platform dynamics depend in part on the quality of social relationships. Moreover, the platform involved community leaders and meetings were held in public with at times a large audience. As has been argued by Mutimukuri and Leeuwis (2004) such public meetings provide limited opportunities for the kind of 'give and take' that is necessary for settling disputes. Rather they provide an environment in which leaders like to manifest themselves, show strength and rally for support. In addition, I was far from an experienced facilitator, and hence lacked the methodological skill to counteract the dynamics that emerged.

Lack of mutually-felt interdependence and urgency may also have negatively affected the dynamics in the platforms. Several authors point to the importance of these factors in securing productive learning and negotiation processes (Fisher and Ury, 1981; Mastenbroek, 1997; Aarts 1998; Leeuwis 2000, Leeuwis and Van Den Ban, 2004). As the Walas regard their stay in Wenchi as temporary, maintaining good relations with the natives is not the highest priority. Moreover, the Walas have other options for accessing land such as the *taungya* system (a system whereby the forestry commission of Ghana gives land out to tenant farmers to grow their food crops while they plant and tend trees for the commission) or relocating to another community when the soils on which they farm become degraded. In addition, there tend to be sufficient Bonos who are still willing to rent out land in view of immediate cash needs associated with e.g. funerals, court cases, house building or health related costs, even if they know this might lead to declining soil fertility (see also Adjei-Nsiah et al., 2006a). Apparently, the Bonos in these respects depend more on the Walas than the other way around. This unequal dependence is to the advantage of the Walas. For them, the higher-level platform at some point presented the risk of the Bonos becoming better organized amongst themselves, which might allow them to take firmer action against soil mining. Not surprisingly, therefore, the Walas became less enthusiastic about negotiating land tenure in the platform.

6.3.2. Stage 2: Experimentation with alternative land tenure arrangements by individual farmers

Research approach and methodology in stage 2

After the failure of the platform process, efforts to support the development of new tenure arrangements shifted to the level of individual landowners and tenants. This was possible since several farmers in the experimental platform had indicated that they would like to experiment with new arrangements. Two landowners and two migrants ‘designed’ (i.e. negotiated) an alternative tenure arrangement in close collaboration with me. I also closely monitored the implementation of the arrangement by having regular contact and discussions with both parties involved. My interest was to find out whether the experiments would indeed allow for more sustainable cropping systems, and which factors would influence their success or failure. After the ending of the ‘experiments’, I evaluated the contract with the landowners and tenants involved by means of an interview. In addition, the basic design of the alternative tenure arrangements was explained to five separate focus groups whereby details from case 1 were used as an example. Subsequently, the groups were asked to discuss the alternative arrangement and rank it against more common tenure arrangements. The focus groups were composed along ethnic lines and the participants coincided largely with the members of the experimental platform (see Table 2 for details).

Results in stage 2: Alternative designs meet with family dynamics

One of the main reasons why tenants were not willing to invest in soil fertility management was payment of high rent which had to be made in advance. The alternative arrangements that were negotiated between the two pairs of farmers had in common that payment of rent was delayed until after the harvest, and took the form of a fixed amount of produce (or its cash-equivalent). In addition, both arrangements included agreements with regard to the crops to be grown. No specific time frame was included in the arrangements (in Wenchi this tends to happen only when advance payment is involved). However, the expectation of both farmers and myself was that the subsequent payment and agreement about cropping systems would result in greater satisfaction for both parties involved. Such mutual satisfaction, then, might form the basis for longer term contracts in the future, as an important condition to soil fertility improvement.

Case 1: alternative land tenure contract involving a Wala migrant, and an elderly landlady

The tenant is a 36 year old migrant (Wala) from Wa in the Upper West region of Ghana. He had stayed in Beposo, a farming community in Wenchi for the past 12 years. Prior to the new contract, the migrant had engaged in a share contract for one year with the 75 year old native landlady. Under the share contract the migrant grew maize on 1.2 ha and cassava on 0.4 ha of land. The cassava was shared equally between the two parties while the maize was shared in a ratio of 1:2 with the landlady taking one portion while the tenant took the remaining two portions. At the end of the share contract, the tenant decided to abrogate the contract and search for another land where he could engage in different contract because the yield he obtained was not commensurate with the amount of labour and resources he invested in the land.

A son of the landowner who did not want the tenant to leave the land asked him to propose an alternative arrangement which he thought would be beneficial to him (the migrant). The tenant then suggested that he would crop 1.2 ha of the land to maize and give 4 bags (two bags each in the major and the minor growing seasons) of the produce to the landowner either in kind or in cash at the prevailing market price. Under this new arrangement, the tenant was responsible for harvesting, shelling and transporting the produce home. He would cultivate the remaining portion of the plot (about 0.4 hectare) to cassava as a soil fertility regenerating strategy, the produce of which was to be shared equally between him and the landowner. The son of the landowner consequently informed the mother who agreed and came to the tenant's house for the contract to be formalized.

In the presence of the tenant's wife, the owner of the house where he (the tenant) resided and another migrant farmer, the agreement was formalized orally. None of the children of the landowner was however, present. In order to secure the contract, the tenant later asked the landowner to put the contract into writing. However, the landowner objected to this suggestion and said that the oral contract in the presence of the three witnesses was enough. The landowner explained that she did not want a written contract because of the cost implication; in the prevailing tenure system, landowners are responsible for the payment of the cost involved in documenting a contract.

At the end of the major cropping season, the tenant realized 16 bags of maize from the 1.2 ha he cropped. He consequently gave the landowner three hundred thousand cedis (US$33.3) a cash equivalent of two bags of maize each weighing 100 kg, which the woman accepted and for which she thanked him.

In the minor season, the tenant cropped the land to maize. A month later, a daughter of the landowner went to the field. When she came home she asked her mother about whom she had given the land to and about the nature of the contract made. Upon hearing of the details of the contract, she objected to the contract in which the tenant was to provide the mother with two bags of maize every season and asked the mother to go and renegotiate with the tenant. Looking at the performance of the maize in the field, the daughter expected that the tenant was going to have a good harvest and therefore felt that giving the mother only two bags of maize was not enough. The landlady then went back to the tenant and demanded that she should be given a third of the produce from the minor season maize crop instead of two bags of maize because the current arrangement was unfair. The tenant rejected the new demand. Consequently the landlady summoned the tenant before some members of the village unit committee to persuade him to give her a third of the maize produce instead of giving her two bags. When the witnesses were called in, they testified that the tenant was supposed to provide the landowner with four bags of maize (two bags each in the minor and the major seasons). The committee members therefore asked the tenant to provide the landlady with the remaining two bags after harvesting the minor season crop.

Not satisfied with the ruling by the unit committee, the landlady threatened the tenant with a court action. The tenant consequently informed me and asked me to accompany him to the landowner and discuss with the family how to resolve the issue. After discussions with the landowner she agreed to take the two bags of maize as agreed originally, but made it clear that she would prefer to go back to sharecropping the next season.

At the beginning of the second year, the landowner told the tenant that she would like them to revert to the share contract which the tenant obliged. However, this time the tenant decided to crop only 0.8 hectare instead of the 1.2 hectares. Later, the tenant confided in me that if the woman insisted on the share contract he would cheat her. What he planned to do was to divide the produce into two after harvest and then hide half and declare the remaining half for sharing, a trick which some tenant farmers have been playing on their landowners. The landowner was an old lady who can hardly walk. The distance from her home to the field was about 11 km and her children also did not frequent this area because of the distance. Upon hearing this, I went back to the landowner with the tenant and assisted in negotiating with her in the presence of her eldest daughter after which they agreed again to the alternative arrangement.

At the end of the major cropping season the tenant harvested 12 bags of maize. As agreed, he gave a cash equivalent of two bags of maize which was ¢440, 000 (US$49) to the landowner. After collecting the money, other relatives of the landowner (who share boundary with the tenant) informed the landlady that the tenant harvested a truck load of maize and therefore the two bags of maize he gave to her did not measure up to the quantity of maize harvested. The landlady upon hearing this decided to end the contract at the end of the second year.

Case 2: alternative land tenure contract involving a migrant (Dagarba) and a landowner

The migrant involved in this contract was a 28 year old Dagarba who had stayed in Wenchi for 2 years. During his first year stay he engaged in a share contract with a native but was not satisfied with the arrangement at the end of the first cropping year.

He approached another landowner (age 42) and asked if he could rent all of his 6 ha of land. Since he had no money to pay for an advance rent (as is usually the case), he negotiated with the landowner to allow him to crop and pay later at the end of the first cropping season. The landowner, however, was afraid that the tenant might not pay if there was a crop failure. He therefore proposed an alternative arrangement to the migrant which would not involve an upfront payment of rent. The landowner first asked the tenant the minimum amount of bags of maize he (the tenant) expected to get when he crops all the 6 hectares of land in one growing season. The tenant mentioned 30 bags of maize. The landowner therefore requested the tenant to give him 9 bags of maize every year to be paid in two instalments of 5 and 4 bags in the major and minor seasons respectively. Under the contract, the landowner mentioned that he would reduce the number of bags to be paid only when there is a crop failure as a result of drought. To encourage the tenant to improve the fertility of the soil it was agreed that during the minor season the tenant would intercrop half of the maize field with cassava, the produce of which would be shared equally between the two parties. If the tenant decided to crop the land only once in a year he would have to pay the full rent in the form of maize. The contract would be renewed after one year if both parties are satisfied. The tenant indicated that if the contract becomes successful, he would plant other crops such as groundnut, cowpea and cassava to ensure sustainable use of the land and still pay the rent in the form of the maize.

The contract was to be put into writing at the beginning of the cropping season before the tenant started cropping. Each party to the contract was to provide three people to witness the contract. When the landowner informed his eldest son of the envisaged contract he objected to it. He explained that giving all the six hectare land to the tenant would deny him (the son) access to land for farming. The landowner, however, ignored his son and went ahead and gave the land to the tenant without putting the contract in writing.

On the day that the tenant was to begin clearing the land, the son of the landowner went to the house of the tenant and threatened him not to step on the land. The tenant being afraid of the threat decided not to go ahead with cropping the land. He did not however inform the landowner of the action of his son.

Evaluation of the experiment by the parties involved as well as different ethnic groups

The fact that one contract never materialized in practice, and that the other was discontinued after 2 years, might easily lead to the conclusion that both experiments were a 'failure'. As we will argue in the next section, the reasons for this failure have more to do with intra-family dynamics than with the contents of the contract *per se*. In this section, we report on the evaluation of the contracts purely in terms of how different parties and communities evaluate the distribution of gains and losses involved. In doing so, we draw mainly on the outcomes of the first case. From a purely economic perspective, the tenants and landowners involved in both cases remain positive about the design of the alternative contract when compared with other arrangements such as sharecropping and land renting (see Table 1).

The tenant involved in case 1 argued that he did not have the financial capital to pay for an advance rent of US$28 per hectare per year. The money that was to be used for the payment of rent could instead be used to hire labour to prepare the land for planting. The tenant obtained 16 bags in the major growing season and another 12 bags in the minor growing season from the 1.2 hectare land. Out of these, he gave four bags to the landlady and the rest (24 bags) became his. He argued that if he shared the produce with the landowner on the basis of 2:1, which is the normal practice with sharecropping, he would only obtain about 18 bags while the landlady would in theory get nine bags.

The landowner herself was satisfied with the arrangement because she would get money twice in a year instead of once in two years when the land is rented for two years. In Wenchi, land is normally rented out at US$ 28 per hectare per year which means that the landlady gets about US$ 33.6 in one year when she rents out her 1.2 hectare land. However, under the alternative arrangement she would get US$ 77.7 from her share of 4 bags of maize in the first year (US$ 33.3 and US$44.4 from 2 bags of maize each in the major and minor season respectively). Thus, under this arrangement, she would receive an extra US$ 44.4 (four hundred thousand cedis) in the first year when compared with land renting. Although with sharecropping the landlady would in theory get 9 bags of maize (instead of 4, see Table 1), the landlady realizes that this option also has disadvantage. First of all, she incurs transportation and shelling costs. She is also aware of the risk of being cheated in the sharing of farm produce by the tenant since she lives about 11 km away from the farm and cannot frequent there. In sharecropping, the tenant usually shares the produce, often in the absence

Table 1: Estimated theoretical benefits accruing to landowners and tenant farmers from 1.2 ha under different land tenure arrangements in a) major cropping season b) minor cropping season and c) major and minor cropping seasons combined in 2004 in Wenchi

Land tenure arrangement	No. of bags of maize obtained		Post harvest cost[a] (US$)[1]		Total revenue (US$)		Net revenue[b] (US$)	
	Tenant	Landowner	Tenant	Landowner	Tenant	Landowner	Tenant	Landowner
a) Major cropping season[2]								
Sharecropping	10.7	5.3	18.3	14.1	177.3	88.3	159.5	74.1*
Rent	16.0	-	32.4	-	250.0[c]	16.7	217.6	16.7
New arrangement	14.0	2.0	32.4	-	233.3	33.3	200.9	33.3
b) Minor cropping season[3]								
Sharecropping	8.0	4.0	16.2	12.0	177.8	88.8	161.6	76.8*
Rent	12.0	-	28.0	-	250.0[c]	16.7	222.0	16.7
New arrangement	10.0	2.0	28.0	-	222.2	44.4	194.2	44.4
c) Major and minor cropping season combined								
Sharecropping	18.7	9.3	34.5	26.1	355.1	177.1	320.6	151.0*
Rent	28.0	-	60.4	-	500.0	33.6	439.6	33.4
New arrangement	24	4.0	60.4	-	455.5	77.7	395.1	77.7

[a]Includes transportation cost from the field, de-husking and shelling cost

[b]Tenant farmer's field operational costs have not been deducted

[c]Cost of land rent has been deducted

[1]Echange rate is ¢9000/ 1US$

[2]Maize was sold at US$16.7/bag of 100 kg

[3]Maize was sold at US$22.2/bag of 100 kg

*In theory this is what should happen but in practice there are risks that reduce revenue for landowners as is illustrated by arguments forwarded by the landlady in case 1 and additional cases reported in Box 1.

of the landowner. The tenant takes his share first and leaves the landowner's share in the field. In addition, the landlady reports that, depending on the circumstances, she may lose up to 50% of the produce due to pests, animals or spoiling in the field. On these grounds, the landlady too continues to feel that the contract is beneficial in principle. Other interviews and stories narrated by community members too suggest that the returns a landowner gets from sharecropping may be far lower than it would be in theory (see Box 1 and Table 1).

The various ethnic groups in the communities were asked as well to evaluate the alternative arrangement from case 1 by comparing it with more common arrangements like sharecropping and land renting.

The Bonos who are the landowners ranked the new arrangement as the best arrangement and sharecropping as the worst arrangement (Table 2). They argued that since at the time of the contract, a hectare of land was being rented at ¢250,000 (US$28), the landowner could have obtained only ¢300,000 (US$33.3), if she had rented the 1.2 ha to the tenant. However, with this new arrangement she earned as much as ¢700,000 (US$77.7), about ¢400,000 (US$44.4) more than what she would have earned if she had rented it out. Moreover in case of crop failure due to drought the tenant was obliged to pay the four bags of maize as stipulated in the contract. Again, they argued that, if the land had been given out for share contract, the farmer could not have obtained more than 2 bags of maize due to cheating by tenant farmers.

The Dagarbas ranked the new arrangement as the most preferred arrangement and sharecropping as the least preferred arrangement. They argued that with this new arrangement, tenants do not have to worry about the problem of having to pay for advance rent before one can start cultivating the land. Thus this arrangement makes it possible for tenants with no financial capital to rent land for farming purposes. Moreover tenants could consume any quantity of the crop on the field while it is yet to be shared without having conflict with the landowner.

The Walas and the Mossi ranked the alternative arrangement as second to land renting. Because of the many problems associated with sharecropping such as conflict over sharing of farm produce, these groups of migrant farmers argue that this alternative arrangement in which rent is paid in the form of farm produce and at crop harvest is a relief for tenants who do not have money to pay for advance rent. Since the tenant is also not obliged to share the produce with the landowner, he could also consume any portion of the produce at any point in time without incurring the displeasure of the landowner. The worry expressed by the Walas and the Mossi, however, is the risk of crop failure in time of drought. Under this arrangement, risk is not shared between the tenant and the landowner as happens

Box 1. **Two examples of the risk of revenue reduction for landowners in sharecropping**

A tenant in urgent need for cash

A forty nine year old landowner loaned his 1.2 ha land to a migrant tenant to cultivate maize on share contract basis. At the end of the cropping season, the tenant gave the landowner only two bowls of maize weighing less than 20 kg, when the landowner requested for his share of the produce. When the landowner sent him before an arbitration body, the tenant pleaded guilty and explained that he sold the maize to enable him get money to send his sick child to hospital.

A tenant attempts to cheat the landowner

A thirty five year-old landowner gave his 1.6 ha land to a migrant tenant to cultivate maize for sharing. When the maize was ready for sharing, the tenant harvested the maize but before he informed the landowner to come for his share of the produce, he had divided the produce into two, hidden one-half of it in a nearby bush and declared only the remaining half for sharing. When the landowner arrived in the field he suspected that the tenant had not declared all the produce. He therefore decided to search the nearby bush and indeed found a heap of maize that had been hidden by the tenant. When the landowner threatened the tenant with a police arrest, the latter bolted and was never seen in the community afterwards.

in sharecropping. Thus, while profit is enjoyed by both landowner and tenant, risk is borne solely by the tenant and in a period of crop failure, the tenant is obliged to provide the landowner with his share of the farm produce.

The Lobis ranked land renting as the most preferred arrangement and the alternative arrangement as the least preferred arrangement. They reason that under the new arrangement, risk is only borne by the tenant unlike sharecropping where risk is shared between the landowner and the tenant farmer.

Table 2: Evaluation of different land tenure arrangements by different focus groups composed along ethnic lines in Wenchi

Contractual arrangement	Ranking order				
	Bonos N=15	Walas N=12	Mossi N=10	Dagarbas N=10	Lobis N=6
Sharecropping	3	3	3	3	2
Renting	2	1	1	2	1
New arrangement	1	2	2	1	3

Note: The Bonos and the Walas involved in the focus group discussion were all part of the experimental platform while four of the Dagarbas and none of the Lobis were members of the platform

Analysis and discussion of findings in stage 2

It transpires from the rankings and surrounding argumentations that, in principle, the alternative arrangement meets with considerable sympathy (see Table 2). While the landowning Bonos rank the arrangement first, the valuation among migrants varies. This is likely to be associated with differential positions in terms of access to cash and pre-existing land-security (Adjei-Nsiah et al., 2006a). While the relatively well-off migrant tenants like the Walas prefer the land rental arrangement, the poorer migrants like the Dagarbas prefer the alternative arrangement which does not involve advance payment of rent. Moreover, the earliest migrant groups who have developed cordial relationships with the Bonos (i.e. the Mossi and the Lobis) are quite satisfied with the existing arrangements which in their case tend to be more stable and less conflict ridden (Adjei-Nsiah et al., 2006a). Thus, for them the alternative arrangement may have fewer added values. Thus, the alternative arrangement seems to offer opportunities especially for poorer landless farmers who cannot afford advance rent payment to access land for farming. Although the arrangement may have positive implications in terms of soil fertility maintenance (i.e. it may allow the use of more favourable cropping systems from a soil fertility point of view, see Adjei-Nsiah et al., 2006b), it is unlikely that the wealthier Walas (i.e. the migrant category that is held most responsible for soil mining by the natives) will voluntarily work with the alternative arrangement on a large scale. In sum, the evaluation of the alternative arrangement in comparison with other arrangements such as sharecropping and land rental indicates that different categories of farmers have different preferences, depending mainly on their financial position and the quality of their relationships with the native landowners, respectively the migrant tenants. Other factors, such as willingness and/or capacity to take risks have not been investigated, but may well play a role as well.

An important lesson to be drawn from stage 2, however, is that the contents of the alternative contract are less important than relational issues of various kinds. Even if many people like the new arrangement, it does not seem to work well due to intra-family dynamics and ambiguities. In both cases, the agreements reached between migrants and landowners do not survive due to the circumstance that other family members (in these cases children) contest the agreement arrived at. The children claimed that their access and interests are jeopardized by the contract, and/or that they have not been properly consulted in the negotiations. In both cases, the landowning contract parties initially did not involve their family members in the negotiations, and neither do they inform them about it. The children involved believe that this is to prevent them from sharing in the benefits of the contract.

My own experience as well as further investigations in the community suggests that the problems experienced in the two cases are not isolated incidents. When I rented a piece of land to carry out experiments with the experimental platform, the contract was disputed by a nephew of the landowner who claimed he needed it for farming. This happened despite the fact that there was a written contract. Although, I could have taken action against the landowner, I decided not to do so because of its implications for my subsequent work with the community. Interviews with tenants and village authorities revealed that younger family members rent out land regularly without the consent of the family head, which resulted in tenants being denied access to the land after having paid rent, or having to leave the land before expiration of the contract. In other cases, contracts were being challenged by family members after the death of the landowner. Similar to what happened in case 1, it is not uncommon for landowners to take back a plot of land before the rent expires, and re-rent it again for a higher price. This is especially when the landowner (or his family) observes that the tenant has had a bumper harvest in the previous season.

At first glance one might interpret the kind of dynamics portrayed simply as cheating both within native families, and between landowners and tenants. However, while self-interest, jealousy and an apprehension from sharing revenues undoubtedly play a role, such practices must be understood in the context of wider struggles for resources, institutional configurations and ambiguities. As Berry (1997, 2002) has indicated, access to land in this region of Ghana is closely intertwined with whether one can successfully claim to belong to a particular family or not, which already goes along with considerable ambiguity and space for negotiation. This is further complicated by the fact that different inheritance systems may apply to pieces of land with different histories, which again enlarges the space for contestation. The natives in Wenchi have a matrilineal inheritance system, which implies that children inherit resources acquired from the family through their mother and uncle; respectively those family resources accumulated or invested in by a male native are inherited by the children of his sisters, and not by his own children. Thus, children can only benefit from such resources as long as their fathers are alive. Some males respond to this by acquiring individual lands (e.g. by entering into a share contract or by buying land from other families) as resources generated and/or acquired through this route cannot be claimed back by the family and can be passed on to their own children (Amanor and Diderutuah, 2001). All this implies that, the question as to who has a legitimate claim to a piece of land depends to a large extent on family history, the history of land-use and land-acquisition, including the history of how resources to buy ‘individual’ lands were generated. Such histories are often not transparent and leave considerable room for interpretation and negotiation, which is why historical narratives play such an important role in land disputes (Berry, 1997, 2002).

Returning to the experiment with new land-tenure arrangement contracts, we can conclude that these efforts failed largely due to the fact that it is simply not clear and transparent with whom such contracts should be made in the first place. This situation suggests that when there is ambiguity in tenure, it becomes difficult for people to experiment with new contractual arrangements. Ambiguities in tenure were complicated further by another source of uncertainty that is inherent to agricultural production, namely the variable climate and ecological conditions that influence production levels obtained. In one of the experiments (case 1) dissatisfaction on the side of the (family of) the landlady arose in particular when the tenant was observed to have a particularly good harvest. A weakness of the contract arrangement was that -unlike sharecropping- it did not have an inbuilt provision to adjust payment to the revenue obtained. It would be interesting to explore whether more flexible contracts could help to ameliorate disputes around rented land. Such an arrangement would be somewhere in between conventional sharecropping and conventional land renting, and seek to combine favourable aspects of share-cropping (e.g. adapting payment to revenue, ex-post payment, agreement about cropping systems) with those of land renting (e.g. clarity about payment, allowing continuous use of land, ease of preventing post-harvest losses, less liable to cheating) while avoiding associated weaknesses.

6.3.3. Stage 3: Exploring institutional arrangements to deal with ambiguity

Research approach and methodology in stage 3

The findings in stage 2 led again to a shift in efforts. It became clear that a better understanding was needed of how people deal with ambiguities in land-tenure, which institutions exist to reduce uncertainties and risks surrounding tenure arrangements, and how such institutions could be strengthened. I conducted informal interviews with key informants such as community leaders and so-called ‘letter writers’ and ‘commissioners of oaths’ who were found to play a role in formalizing contracts. Two community leaders, three letter writers and one commissioner of oaths were interviewed. Subsequently, a survey was conducted among 33 tenants to find out how many tenants had written contracts. This was done by first using snowball technique to make a complete list of all migrants in the three communities and their tenancy status. From the list, all tenant farmers who rent land were interviewed to find out whether they had written contracts or not.

Results in stage 3: increased use of written contracts

The key informants all signalled that, as a response to the numerous land disputes occurring, many tenants are now interested in written contracts as a means of formalizing and securing their agreements with landowners. The survey carried out subsequently among tenant farmers indicated that in 2005, 13 of the 33 farmers interviewed indicated that they had written contracts. Key informants claimed that this figure is considerably higher than in previous years. Tenants indicated that they resort to written contracts especially when the contract exceeds one year and/or involves a large sum of money. When trust develops gradually between the landowner and tenant after two contract terms or so, subsequent contracts are sometimes made without documentation. It is relevant to note that in the research area written contracts are only drawn up for land renting, and not for sharecropping or other tenure arrangements.

Contracts are made between the landowner and the tenant farmer and, according to respondents, should be witnessed by at least two people provided by each of the parties. Preferably the witness of the landowner should be a close relative of the landowner who would be in a position to challenge the validity of the contract. Such a person could be the eldest son or daughter of the landowner in the case of private land, or a nephew, a sibling or a family head in the case of family land. However, as one of the earlier cases demonstrates, this does not always happen as landowners may well be reluctant to let close relatives know of contracts made. Instead, some landowners solicit the assistance of people outside the family with no right in the land to witness the contract.

Typically, written contracts indicate the land area, the location of the land and the duration of the contract, and include names and thumbprints or signatures of landowner, tenant and their witnesses. Both the tenant and landowner receive a copy. The documents are kept at a secure place and produced before an arbitration authority when the contract is disputed.

In Wenchi, written contracts are not validated by public officials or local authorities (as reported elsewhere by Lavigne Delville, 2003). Institutions that do play an important role in preparing and documenting contracts in Wenchi are so-called letter writers and commissioners of oaths. Commissioners of oaths are normally retired civil servants (e.g. police officers, teachers, court registrars, etc) who are licensed or registered to prepare official written documents (such as contracts and wills) for individuals at a fee, and are usually located in larger towns. Letter writers tend to be individuals who operate secretarial businesses in smaller communities at a fee. Contracts prepared by commissioners of oaths have official legal backing while contracts prepared by letter writers normally do not, unless the letter writer is licensed to perform specific tasks. Two commissioners of oaths are located in Wenchi district, while several letter writers are located in the communities. Reportedly, their number has grown in recent years; in Beposo village alone there were three letter writers. As the commissioners of oaths charge higher fees and are only located in Wenchi, most people prefer the services of the letter writers. It is usual that the party who receives money pays for the preparation of the contract, which simultaneously serves as a kind of 'receipt' for the paying party. Thus, the cost of putting the contract on paper is borne by the landowner only, which sometimes deters them from engaging in written contracts. Some tenant farmers are, however, willing to pay for the cost when the landowner is unwilling to do so.

In addition to preparing the contracts, commissioners of oaths and letter writers frequently serve as principal witnesses during land disputes. Such disputes are often brought before unit committees and/or community elders. The unit committees are local government structures which operate at the community level. The community elders which constitute the traditional authority are made up of the chief and his elders. An aggrieved individual in a land dispute may decide to send the case to any of the two bodies, depending on where (s) he thinks the case may receive a fair hearing. These two bodies serve as the main arbitration bodies in the communities who settle land disputes at the local level. Despite the important roles that they play, their decisions are never binding. A person who does not trust the fairness of the two bodies or feels aggrieved by a decision may decide to seek redress at a district magistrate court or even at a higher court.

Analysis and discussion of findings in stage 3

The increased use of written documents to secure and formalize contracts has also been reported by others and elsewhere in Africa (Lavigne Delville, 2003; Lavigne Delville et al., 2001; Amanor and Diderutuah, 2001). The emergence of this alternative way of dealing with land tenure agreements can be interpreted as a local response to changing socio-economic circumstances, including increased pressure on the land as well as frequent tension between natives and migrants concerning land tenure. It shows that local actors engage actively in solving problems, in this case by developing institutional innovations (Lavigne Delville, 2003) in the form of written contracts for land renting and associated rules and procedures, as well as the growth in the numbers of service providers. These developments demonstrate the self-organizational capacity of local actors in bringing about institutional innovations in land tenure systems where current arrangements for managing conflict are no longer sufficient (see also Le Meur, 2002).

However, the current institutional innovation that we have observed did certainly not solve all problems around land tenure in Wenchi. As we have seen, written contracts in Wenchi are only used for land renting and tend to be restricted to contracts that involve money. They do, for example, not cover sharecropping even if sharecropping arrangements go along with considerable tensions as well, especially regarding the sharing of produce. Written sharecrop contracts are reportedly common in the citrus and oil palm belt of the Eastern region of Ghana (Amanor and Diderutuah, 2001). In addition, a written contract alone is not an absolute guarantee of tenure security. When not witnessed by the right persons, the contract can be successfully challenged. With the situation that I experienced (see stage 2), none of the two people who witnessed the contract was a close relative of the landowner. Even if written contracts may enhance transparency on what is agreed upon, and may contribute to relevant family members being informed about them (as witnesses or otherwise), the ambiguities around land tenure are such that disputes still arise easily. And when such disputes arise, tenants often hesitate to strain their relationships with their communities of residence by engaging them in legal battles which may be expensive, time consuming and sometimes run into years. Finally, the securing of a written contract requires the consent of all parties, and tenants in particular are not always in a position to persuade native landowners to co-operate.

In all, we see that local actors have already worked towards new institutional arrangements that may contribute to reduction of uncertainties and conflict around land tenure. However, there is still considerable scope for the further development of such innovations. Possibilities in this respect may include (a) the development of written contracts that somehow make sharecropping less vulnerable; (b) contractual provisions for renting that create a link between the level of rent and the level of revenue obtained; (c) clear and agreed upon rules as to who can contract out what land, and who should be involved as witnesses to make a contract valid; (d) mechanisms for parties to find out what the status of particular lands and landowners is vis-à-vis such rules; (e) increased involvement of local authorities in validating contracts; (f) better licensing and/or certification of letter writers; and (g) strengthening customary and local institutions to manage land related conflicts at the local level. These are just examples of possible strategies that may be pursued.

6.4. Conclusion

We have reported on a long action research journey in the social realm that began when our 2002/2003 diagnostic study (Adjei-Nsiah et al., 2004) suggested that we needed to work on alternative land tenure arrangements if we wanted to contribute to the creation of better conditions for soil fertility improvement. Our initial approach was to bring stakeholders together in a platform to engage in the collaborative design of new arrangements. These efforts were stranded mainly because conditions conducive for learning and negotiation appeared to be lacking. We then proceeded with supporting experimentation with new kinds of tenure arrangements between individual landowners and tenants. Although the type of arrangement experimented with was appreciated in principle by some groups of farmers, many problems occurred during the implementation. While we had worked on the contents of the contracts, more pressing problems appeared to be associated with ambiguities regarding who is to be involved in contracts in the first place. In the final stage of the journey, we set out to gain a better understanding on how such ambiguities could be tackled, and found that local actors themselves had already made some progress in working towards institutional innovations without us noticing initially. One could say that, in a sense, we have ‘missed the point’ repeatedly during our action research, despite the fact that we – and the program of which we were part – deliberately invested considerable time and effort in so-called ‘diagnostic studies’ (see Röling et al., 2004). In other words, we made several assumptions and/or ‘pre-analytical choices’ (see Röling et al., 2004) that proved misguided in retrospect. Although we do not exclude the possibility that alternative ways of carrying out the research (e.g. working with an inter-disciplinary team of researchers in the field, instead of with an individual PhD student with an inter-disciplinarily group of supervisors 'at a distance') might have led to a quicker understanding of the complexity of the situation, we want to argue that 'missing the point' at times is inevitable when engaging in (action) research, and that the recognition of it is in fact a sign of learning and progress. If researchers want to contribute to change and development and engage with communities, they need to start somewhere and find an entry point on which local actors are willing and motivated to work. In this case, the initial entry point was 'optimizing locally developed technical strategies for dealing with soil fertility'. Sustained critical reflection and diagnosis during collaborative technical experimentation with farmers led to progressive insight and greater attention for the social realm. Although unanticipated problems and even conflicts occurred in the effort to address social issues, these were functional in that they led to sharper problem definitions and new courses of action, not only on the side of the researcher, but also on the side of societal stakeholders. Change and innovation processes eventually depend on action, and action is a critical condition for and component of learning (Kolb, 1984; Leeuwis and Van Den Ban, 2004). In complex situations, it is fundamentally impossible for a researcher to come in with a full understanding of the situation, and even if we had come in better prepared (and/or with a team) and started the action research differently, we would have discovered flaws in our thinking, and faced the need to adapt to the entry points of local actors as well as to the unpredictable outcomes of social (inter)action. An important conclusion to be drawn is that action research requires continuous 'diagnosis' and critical reflection on assumptions and outcomes in order to flexibly steer research into relevant directions.

References

Aarts, M.N.C., 1998. Een Kwestie van Natuur; een Studie naar de Aard en het Verloop van Communicatie over Natuur en Natuurbeleid. Published doctoral dissertation. Wageningen agricultural University, Wageningen.

Addo-Fening, R., 1987. Customary land-tenure in Akyem-Abuakwa. Universitas, 9, University of Ghana, Legon.

Adjei-Nsiah, S., Leeuwis, C., Giller, K.E., Sakyi-Dawson, O., Cobbina, J., Kuyper, T.W. and Van Der Werf, W., 2004. Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: implications for interdisciplinary action research. NJAS – Wageningen Journal of Life Sciences, 52:331-348.

Adjei-Nsiah, S., Leeuwis, C., Sakyi-Dawson, O. Giller, K.E. and Kuyper, T.W., 2006a. Exploring diversity among farmers for orienting inter-disciplinary action research on cropping system management in Wenchi, Ghana. International Journal of Agricultural Sustainability (in press)

Adjei-Nsiah, S., Kuyper, T.W., Leeuwis, C., Abekoe, M.K. and Giller, K.E., 2006b. Cassava improves soil fertility? Soil fertility management practices among small-holder farmers in the forest-savannah transitional agro-ecological zone of Ghana. Field Crops Research (Submitted)

Amanor, K.S., 1993. Wenchi Farmer Training Project: Social/environmental baseline study: Unpublished report to Overseas Development Administration, Accra, Ghana.

Amanor, K.S. and Diderutuah, M.K., 2001. Sharecropping in the oil palm and citrus belt of Ghana. IIED/GRET, London.

Bawden, R., 1994. Creating learning systems: a metaphor for institutional reform for Development. In: I. Scoones & J. Thompson (eds.), Beyond farmer first. Rural people's knowledge, agricultural research and extension practice (pp. 258-263) London: Intermediate Technology Publications. London.

Berkes, F. & Folke, C. (Eds), 1998. Linking social and ecological systems. Management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK

Berry, S., 1993. No Condition is Permanent– The Social Dynamics of Agrarian Change in Sub-Saharan Africa. The University of Wisconsin Press, Madison.

Berry, S., 1997. Tomatoes, land and hearsay: property and history in Asante in the time of structural adjustment. World Development, 25: 1225-1241

Berry, S., 2002. The Everyday Politics of Rent-Seeking: Land Allocation on the outskirts of Kumasi, Ghana. In K. Juul and C. Lund (Eds.) Negotiating Property in Africa (pp. 107-133). Heineman, Portsmouth.

Collinson, M. P. (Ed), 2000. The history of Farming Systems Research. CABI Publishing, Wallingford.

Crook, R., 2005. State courts and the regulation of land disputes in Ghana: the litigants' Perspective, IDS Working Paper 241. Institute of Development Studies, Brighton.

DFID, 2000. Justice and Poverty Reduction: Safety, Security and Access to Justice for All. DFID, London.

Fisher, R. and Ury, W., 1981. Getting to yes: Negotiating agreement without giving in. Penguin Books Ltd, Harmondsworth.

Fraser, D.G.E., 2004. Land tenure and agricultural management: Soil conservation on rented and owned fields in southwest British Columbia. Agriculture and Human Values, 21: 73-79.

Fred-Mensah, B.K., 1999. Capturing ambiguities: Communal conflict management alternative in Ghana. World Development, 27: 957-65.

Gavian, S and Ehui, S., 1999. Measuring the production efficiency of alternative land tenure contracts in a mixed crop-livestock system in Ethiopia. Agricultural Economics, 20: 37-49.

Gavian, S. and Fafchamps, M., 1996. Land tenure and Allocative Efficiency in Niger. American Journal Of Agricultural Economics, 78: 460-471.

Geels, F., 2002. Understanding the dynamics of technological transitions. A co-evolutionary and socio-technical analysis. Twente University Press, Enschede.

Kolb, D.A., 1984. Experiential learning: Experience as the source of learning and development. Prentice-Hall, Englewood Cliffs.

Lavigne Delville, P., 2003. When Farmers Use "Pieces of Paper" to Record Their Land Transactions in Francophone Rural Africa: Insights into the Dynamics of Institutional Innovation. European Journal of Development Research, 14: 89-109.

Lavigne Delville, P., Toulmi, C., Colin, J.P. and Chauveau, J.P., 2001. Negotiating Access to land in West Africa: A Synthesis of Findings from Research on Derived Rights to Land. IIED, London.

Le Meur, P.Y., 2002. Trajectories of the Politicisation of Land Issues: Case Studies from Benin. In K. Juul and C. Lund Eds.) (pp. 135-155). Negotiating Property in Africa. Heineman, Portsmouth, NH.

Leeuwis, C., 2000. Re-conceptualizing participation for sustainable rural development. Towards a negotiation approach. Development and Change, 31: 931-959.

Leeuwis, C. and Van Den Ban, A., 2004. Communication for Rural Innovation: Rethinking Agricultural Extension (3rd edition). Oxford: Blackwell Science, 412 pp.

Maarleveld, M. and Dangbégnon, C., 1999. Managing natural resources: A social learning perspective. Agriculture and Human Values, 16: 267-280.

Mastenbroek, W.F.G., 1997. Onderhandelen. Uitgeverj het Spectrum B.V. Utrecht.

Mutimukuru, T. and Leeuwis. C., 2004. Process leadership and natural resource management in Zimunya communal area. In: Moll, H.A.J., C. Leeuwis, E. Manzungu and L.F. Vincent (Eds.) Agrarian institutions between policies and local action: Experiences from Zimbabwe. (pp. 189-216). Weaver Press, Harare.

Ostrom, E., 1990. Governing the commons. The evolution of institutions for collective action. Cambridge University Press, Cambridge.

Pretty, J.N. and Chambers, R., 1994. Towards a learning paradigm: new professionalism and institutions for agriculture. In: I. Scoones & J. Thompson (Eds.), Beyond Farmer First: Rural people's knowledge, agricultural research and extension practice, (pp. 182-202). London: Intermediate Technology Publications Ltd.

Rogers, E.M., 1983. Diffusion of innovations, 3rd edition. Free Press, New York.

Röling, N.G., Hounkonnou, D., Offei, S.K., Tossou, R.C. and Van Huis, A., 2004. Linking science and farmers' innovative capacity: diagnostic studies from Ghana and Benin. NJAS-Wageningen Journal of Life Sciences, 52: 211-235.

Röling, N.G. and Jiggins, J., 1998. The ecological knowledge system. In: N.G. Röling and M.A.E. Wagemakers (Eds.), Facilitating Sustainable Agriculture. Participatory Learning and Adaptive Management in times of Environmental Uncertainty, (pp. 283-307). Cambridge University Press, Cambridge, UK.

Röling, N.G. and Wagemakers, M.A.E. (Eds.), 1998. Facilitating sustainable agriculture. Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, Cambridge, UK

Smits, R., 2002. Innovation studies in the 21st century. Questions from a users perspective. Technological Forecasting and Social Change, 69: 861-883.

Steins, N and Edwards, V., 1999. Platforms for collective Action in Multiple Use Common Pool Resources. Agriculture and Human Values, 16: 241-255.

Van Veldhuizen, L., Waters-Bayer, A. and De Zeeuw, H., 1997. Developing technology with farmers. A trainer's guide for participatory learning. Zed Books Ltd, London

CHAPTER 7

General discussion

7.1. General Discussion

The limited impact of agricultural research in improving the livelihoods of smallholder farmers in sub-Saharan Africa has been blamed partly on inappropriate model for generation and diffusion of agricultural technology. In the transfer of technology model of agricultural research, research priorities are largely determined by scientists who then develop technologies in a controlled environment and then hand them over to agricultural extension to transfer to farmers (Chambers and Jiggins, 1987). These practices are not fully informed by the views and the needs of users (i.e. the resource-poor farmers) who are the ultimate clients of the research, neither are their knowledge, creativity and expertise recognised. In order to make agricultural research more relevant to small-holder farmers in sub-Sahara Africa, a new approach of doing research has been proposed. In this research approach called the ‘Convergence of Sciences’, research becomes a collective enterprise in which different stakeholders’ values, knowledge and expertise are negotiated to produce results that meet the needs and circumstances of farmers. This study was conducted within the framework of the Convergence of Sciences programme which is being implemented by a consortium of the Université d’Abomey-Calavi, Benin; the University of Ghana, Legon, Ghana; and Wageningen University and Research Centre, Wageningen, the Netherlands with funding from the Interdisciplinary Research and Education Fund (INREF) of Wageningen University; the Directorate General for Development Cooperation of the Dutch Ministry of International Affairs (DGIS); and the FAO’s Global IPM facility (GIF).

7.2. Objectives and design of the study

The initial aim of this study was to facilitate the development of soil fertility management innovations among small-holder farmers in the forest / savannah transitional agro-ecological zone in Wenchi. The main focus of the study was to jointly develop soil fertility management innovations with relevant stakeholders using their values, knowledge and expertise through negotiations to produce results relevant to the different sections of the farming community. The specific objectives of the study were: (i) to explore farmers’ soil fertility management practices in Wenchi district and the social rationale of the different technical practices; (ii) to explore diversity among farmers in order to orient interdisciplinary action research on cropping systems to meet the needs of different groups of farmers; (iii) to evaluate the efficacy of different soil fertility management strategies being used by farmers; and (iv) to explore social and institutional dimensions of soil fertility management in order to contribute to the development of new social arrangements as an integral part of soil fertility management innovation. Between 2002 and 2003, a diagnostic study was carried out in Asuoano, a farming community in Wenchi district of Ghana to explore together with the farmers, their soil fertility management needs in order to ground the action research in the needs of the local farming community. This was immediately followed by on-farm experimentation with three farmer research groups established soon after the diagnostic study in three nearby communities close to Wenchi namely Asuoano, Beposo and Droboso.

7.3. Cropping systems, land tenure and social diversity

The main findings of this study have been discussed in the individual chapters of this thesis. Therefore our goal here is to integrate these findings and discuss how cropping systems, land tenure and social diversity interact to affect soil fertility management practices.

Cropping systems and soil fertility management practices varied considerably among and between native and migrant farmers. These differences were attributed to interplay between structural conditions and active human agency.

In the research area, different groups of migrants exist, each with different history of migration. The earlier groups of migrants (the Mossi, Lobis and Dagarbas) migrated into the area between 1940s and 1960s and have developed long-standing relationships with the natives. They regard their stay in Wenchi as permanent. The later group of migrants (the Walas) migrated into the area in the early 1990s. They regard their stay as temporary and have strong ambition to return to their home of origin. The differences in ambitions with regards to the stay in Wenchi go alongside with differences in cropping systems and soil fertility management practices. The earlier migrants tend to use cropping practices (which involve intercropping and/or rotation of yam and maize with cassava) which to some extent can regenerate soil fertility. On the other hand, the Walas who arrived in the area in the early

1990s and have strong ambition to return home use cropping practices (mainly continuous maize cropping with minimal external inputs) that tend to mine the soil of nutrients.

Among the natives, cropping systems and soil fertility management practices also differ significantly between male and female farmers. Although most female farmers are aware that maize and cowpea have more ready market than cassava and pigeonpea, they experience several obstacles in the cultivation of these crops including inadequate access to production resources such as labour, cash, credit and inputs (chemical fertilisers, herbicides and insecticides) which are essential for successful cultivation of maize and cowpea. They also consider the cultivation of these crops as risky farm enterprises due to the risk of crop failure as a result of unreliability of rains. For this reason, they resort to the cultivation of crops such as cassava and pigeonpea (which are less demanding with regards to labour and external inputs) and which can regenerate soil fertility to some extent. Native male farmers practise sole maize cropping but in contrast to their female counterparts, they combine this with long term rotational strategies.

In Wenchi, cropping activities tend to be concentrated closer to the communities thereby leading to gradients of increasing soil fertility with distance from the settlements. In most part of Eastern and Southern Africa where livestock is an important component of the farming system, organic manure is normally applied to fields closer to the homesteads leading to gradients of decreasing soil fertility with distance from the homesteads (Tittonell et. al., 2005; Zingore, 2006). In Wenchi, livestock seems to be less important and are poorly integrated in the farming system and therefore organic manure is not used in soil fertility management which probably explain why there is gradient of increasing soil fertility with distance from the settlements.

The landowning natives tend to concentrate their cropping activities on fields closer to the settlements which are less fertile while lands far away from the settlements and which are relatively fertile are either rented or given out to migrants for sharecropping. When such lands are given out to migrants for sharecropping, monitoring of arrangement becomes difficult because of distance, often resulting in mistrust (since tenants can easily hide some of the produce without the landlord knowing it).

One of the reasons for the differential concentration of cropping activities by migrants and natives is that tenants are prepared to pay money for land rented or are prepared to engage in sharecropping arrangement only when the land is relatively fertile. For tenants who rent land, renting relatively fertile land will allow them to crop the land continuously for two years both in the major and the minor cropping seasons before the land loses its fertility. Another reason for the differential concentration of cropping activities between natives and migrants is that cropping activities of female native farmers especially, which involve cultivation of food crops such as pigeonpea, cassava and yam in complex intercropping systems do not require such fertile land and therefore are concentrated around less fertile fields within the immediate vicinity of the settlements. In fact, it is widely acknowledged among the farmers that legumes, particularly pigeonpea and cowpea do not produce enough grains when cultivated on fields which are more fertile. Besides this, these grain legumes are intentionally cultivated closer to the house to facilitate easy harvesting and/or spraying against insects in the case of cowpea.

For these reasons, continuous maize cropping, mainly practised by migrants, tends to be carried out on fields far away from settlements which are relatively fertile. Cassava cropping is carried out both on fields closer to and far away from settlements, while rotations involving cowpea and pigeonpea are practised on fields closer to the settlements.

At the end of the diagnostic study, an agenda for experimentation was drawn to experiment on the effectiveness of both long-term technical practices such as cassava cropping, pigeonpea cropping and bush fallowing and short-term technical practices such as continuous maize cropping and rotations involving cowpea and groundnut. We included mucuna because of its widely known soil fertility improvement potential.

On both farmer and researcher-managed plots, yields of maize were higher on plots previously cropped to cassava and pigeonpea compared with the other cropping sequences. Returns on investment were also higher with cassava/maize and pigeonpea/maize rotations compared with the other rotations. The beneficial effects of cassava on maize grain yield were mainly due to the relatively high amount of recycled N returned to the soil through the leaf litters and green leafy biomass of cassava. Other possible effects may include reduction in weed incidence as a result of the suppression of weeds by the cassava canopy. Although we did not study the possible beneficial effects of mycorrhizal associations, there are indications that these could play a possible role as suggested by the very large initial effect of cassava on maize dry matter at 3 weeks after planting. Saïdou (2006) also reported a major contributing effect of cassava on subsequent crops through mycorrhizal associations. The high return on investment obtained both with cassava/maize and pigeopea/maize rotations were due to high storage root yield of cassava and high grain yield of the pigeonpea as well as low labour and input requirements of these crops. It is therefore rational for female farmers with inadequate access to production resources to adopt these rotational practices even if the market for these crops seems not to be well developed. Although, yield of maize after mucuna/maize/mucuna was comparable to that after cassava, return on investment was far less than that obtained with cassava/maize, pigeonpea/maize or cowpea/maize/cowpea/maize due to the lack of returns during the period that mucuna is growing in the field despite investments made in labour and input. It was therefore not surprising that none of the collaborating farmers expressed interest in using mucuna as a soil fertility improvement strategy.

7.4. Experimentation with farmers

To achieve our aim of developing soil fertility management innovations with farmers, we established an experimental platform through which regular interactions with the intended beneficiaries (i.e. the farmers) and other stakeholders were made possible. This provided an opportunity for taking local knowledge needs into account. More importantly, it allowed farmers' veto to be brought to bear upon the research during the experimentation. For instance during the negotiations of the research protocols, a suggestion to incorporate the biomass of mucuna, pigeonpea and speargrass into the soil was rejected by the farmers who maintained that on the smaller experimental plots it would be easy but may not be applicable under their conditions due to the amount of labour involved, given that they had limited access to resources such as labour, cash and credit. Thus positioning farmers as active partners in research and engaging them as co-researchers and empowering them to have control over research enables scientists to ground research in the needs and circumstances of farmers taking into consideration their livelihood aspirations and their access to resources such as labour, land, cash, credit and input.

All the technical practices experimented with the farmers to some extent increased the yield of subsequent maize crop grown afterwards compared with yields on the plots previously under speargrass fallow. Although there are no records to show which of the technical practices experimented with are being used by which group of farmers, during the preference ranking exercises carried out with the groups after the experimentation, different groups of farmers indicated which of the practices they would like to use. The preference for a particular practice depended on access to resources such as land, labour, credit, cash and input and the farmer's livelihood aspirations.

As has been pointed out by de Jager (2005), these low input technical practices can be seen as a defensive reaction to adverse economic conditions. According to de Jager (2005) these practices are relatively efficient at low productivity levels and are attractive to farmers when prices of outputs are low and prices of inputs are high.

Looking back at their involvement in the experimentation, many farmers commented that they felt their confidence level and innovative capacities had improved. According to the farmers, the quality of their experimentation had improved when compared to the past, as they saw the need to compare many things at the same time. They demonstrated this by conducting individual experiments on their own fields for further validation of research results obtained on the joint study plots. In Chapter 4, we reported that soon after the experimentation on cowpea varieties on the joint plots, about 50% of the farmers collected different cowpea varieties and evaluated them on their own individual fields. This was however not an isolated case. There was another farmer in one of the groups, who after the cowpea experiment went to the market to select a cowpea variety with high consumer demand after interviewing the market women and evaluated it on his own field in two different growing seasons to find out which growing season will be suitable for that variety. In another instance, after evaluating different cassava varieties on joint plots, the farmers again selected different materials for further evaluation on their own fields. Again, one woman from one of the groups, after our joint experimentation on different rotational practices, evaluated the performance of maize on two separate plots she had cropped to cowpea and groundnut in the previous season.

Although action research allows farmers to learn and experiment on their own, it requires good skills in adult learning and facilitation (Defoer, 2002). In addition it is time-demanding and puts a lot of demand on farmers' time. For this reason, other farmers in the communities who were salaried workers but were interested in the joint study were excluded largely from participating. In one community, four native men (all of whom were salaried workers), who were among the first group of farmers we started with, had to withdraw their membership because of the need for frequent meetings. In another community there were three primary school teachers who were interested but had to withdraw after the first two meetings due also to the frequent meetings. Thus only full-time farmers without any other commitments outside farming could avail themselves for the study.

Unlike many research and development projects which create artificial conditions to induce local innovations (e.g. through temporal provisions of inputs) our collaborating farmers were not provided with any incentives like inputs and credit to induce them. The farmers were willing to collaborate with us because we recognised them as a source of innovation for improving soil fertility. In fact, they were willing to work with us to prove to us that they also have knowledge to share with scientists as a result of their claim on cassava as a soil fertility regenerating crop. As the leader of one of the farmer groups commented during our concluding community meeting, "When Mr. Adjei-Nsiah came here at the beginning, he did not know how we use cassava and pigeonpea to restore the fertility of our soil but we did experiment with him and taught him how we restore the fertility of our soils with these crops and now he is convinced that cassava cultivation can restore soil fertility". However, inspite of the heavy investment that have been made in building the capacities of these local farmers, no efforts were made to link these farmer groups to other change agencies to ensure continuity after the PhD project.

7.5. Reflections on the research process

7.5.1. Misplaced notion about soil fertility management and the need for continuous diagnosis in action research

The entry point of this study was how to optimise locally developed technical strategies for dealing with soil fertility decline, after a study by Offei and Sakyi-Dawson (2002) revealed the existence of these practices, some of which contradict with what were perceived to be dominant scientific beliefs. During the initial diagnosis (Chapter 2), we found significant differences between native and migrant farmers with respect to farmers' technical farming practices and attributed this to differential land tenure arrangements. However, continuous critical reflection and diagnosis during collaborative technical experimentation with farmers led to a progressive insight into the complex situation. Consequently, we carried out further exploration of diversity among the farmers to deepen our understanding of soil fertility management (chapter 3). This further exploration revealed that what we initially interpreted as a problem of soil fertility decline and farmers' soil fertility management strategies' are in fact closely intertwined with practices, aspirations and strategies in totally different spheres.

Even during the later part of the study, new insights were discovered which had not yet been explored, such as the spatial differentiation of the different rotational practices and increasing soil fertility gradients with distance from settlements which became apparent after a visit by other scientists (Nico de Ridder and Mark van Wijk together with Edward Yeboah) working on another project (AfricaNUANCES) to the same study area. This issue was highlighted because these scientists came in specifically looking at the system from a 'comparative perspective' with similar work in other countries.

The insights generated through these shifts have shown that the notion about farmers' technical farming practices as 'soil fertility management' was misplaced and was probably due to our poor understanding of socio-economic and institutional factors that determine farmers' technical practices as well as our own professional bias as scientists. Therefore in order to gain a better understanding of farmers' situations which may be complex, it is necessary and fruitful to explore and diagnose continuously in action research.

7.5.2. Difficulties in social experimentation

After our initial diagnosis (Chapter 2), we concluded that our action research should not only remain in the technical realm but should also include social experimentation if all sections of the farming communities were to benefit from our efforts. Specifically we suggested negotiation of and experimentation with alternative land tenure and/or contractual arrangements.

After failing to bring stakeholders together on a platform to engage in collaborative design of alternative arrangement, we decided to support experimentation of alternative land tenure arrangement initiated by some landowners and tenant farmers. Initially we thought that this was going to be a simple task. However, the implementation became more difficult than we anticipated because of institutional ambiguities in the land tenure. Although the arrangement experimented with was acceptable in principle by most sections of the farming communities, its implementation became difficult, because other family relations, specifically children of the landowners felt that they were either not properly consulted during the negotiations or their interest was jeopardized by the contract. The problem was that it was not so clear and transparent as to whom the contract should be made in the first place.

Although certain initiatives had already been taken by the local actors towards developing institutional arrangements to reduce ambiguity from where we could have taken off and explored, we could not recognise it initially and assumed that nothing had been done towards that. Such mistakes in initial assumptions are however, unavoidable since in complex situations, it is difficult, if not impossible for researchers to have a full understanding of the situation within a relatively short period of time. Therefore if action researchers are to steer research into a relevant direction continuous diagnosis and reflection on earlier assumptions are inevitable.

7.5.3. Compatibility between PhD project and action research

In a complex farming situation, it is difficult to understand the system within a reasonably short period of time since this requires considerable effort and time on the part of the action researcher. A four year PhD project - i.e. the context in which our study took place - does not perhaps constitute the ideal time horizon for this study. Such a complex study would probably be better conducted by an interdisciplinary team of researchers who would have a quicker understanding of the complex situation.

In action research, elements such as the use of control, replications and control of non-experimental variables that are required in scientific research to maintain high quality (Gladwin et al., 2002) are difficult to be grounded in the reality of farmers. For example, in our study, farmers did not see the need to maintain control plots when it was obvious that they were not going to have a good harvest on those plots. Similarly, while farmers agreed that biomass of cowpea, groundnut and cassava should be incorporated into the soil to have greater impact on the maize crop to be cultivated; they were not convinced that the same treatment should be applied to biomass of pigeonpea, *Imperata cylindrica* and mucuna because of the difficulties in incorporating these into the soil. Farmers argued that these materials should be burnt in order to reduce labour cost for incorporating them into the soil thereby introducing variability into the treatments. Thus a great challenge in action research is how to balance the requirements for scientific rigour and the demand for research results that meet farmers' needs and priorities (Morford et al., 2004)

In this research, this problem was resolved by conducting an adapted form of what ICRISAT has called 'mother and baby trials' (Johnson et al., 2003). The mother and baby trial is a participatory research methodology designed to improve the interaction among farmers and researchers. The mother trials are researcher-designed and conform to requirements for scientific analysis and the baby trials provide a single replicate. This design allows farmers to actively engage in experiments and researchers to understand the technology in the farmers' context.

7.6. Implications of the Study

7.6.1. Implications for research and extension policy

The study has shown that involvement of farmers in the development of innovation using their knowledge, values and expertise is crucial for developing innovation that meets the needs and circumstances of the farmer. This has been recognised by several reports on ensuring sustainable food security in Africa (Anon, 2001; IAC, 2004). This however requires a new role for research and extension as interactive researchers and facilitators. Most technical scientists and extension workers however, are handicapped in terms of adult learning and facilitation skills (Defoer, 2002; Stoop and Hartig, 2005). Thus the universities have an obligation to prepare their agricultural graduates better to cope with facilitation skills needed for interactive research. Institutional reforms are also required in the public research and extension systems to change reward and incentive structures so that scientists and extension officers become more responsive to the needs of farmers (Anon, 2001). To meet this difficult challenge of making agricultural research more responsive to the needs of farmers, there is an urgent need to increase available funding for research (Anon, 2001; IAC, 2004). The Inter-Academy Council (2004) report recommends that agricultural research funding to national agricultural research systems should increase in real terms by at least 10% annually to 2015. The farmer must also be seen and regarded by extension as an active knowledge expert who is capable of making complex decision instead as an ignorant and passive user who is provided with modern technology by external experts (Röling and van de Fliert, 1994).

7.6.2. Implications for agricultural education policy

This study has shown how natural scientist's efforts to improve existing technical strategies were combined with a study on their social dimension whereby efforts were made to analyse social and institutional dimensions of these technical practices that could contribute to the development of new social arrangement as an integral component of soil fertility innovation. By taking several courses in social science, and engaging in regular interactions with both natural and social scientists, it became possible to conduct such a 'hybrid' study despite being originally trained as a natural scientist.

Giving scientists multidisciplinary training in our universities and engaging in cross-disciplinary research programmes will enable researchers to see relevant connections between technical and social dimensions of research problems. The need for reform in the university curricula to lay emphasis on multidisciplinary approaches to better prepare scientists for innovation, knowledge and information is well recognised (Stoop and Hartig, 2005; IAC, 2004). This requires changes in the academic syllabi of our technical (including agricultural sciences) universities to include courses related to the humanity notably anthropology, rural sociology and communication and facilitation skills that will equip agricultural scientists with the necessary skills to communicate and dialogue effectively with various stakeholders (Stoop and Hartig, 2005).

7.6.3. Implications for land tenure policy

The evidence of the link between land tenure and investment in soil fertility and the institutional ambiguities in the land tenure system reported in this thesis suggest the need for policy reforms in the land tenure institution in Ghana. Land relations and tenure reforms in Africa have been subjects for discussion during the past two decades (Atwood, 1990; Migot-Adholla et al., 1991; Platteau, 1992; McAuslan, 1998; Fortin, 2005). Land tenure reform is supposed to consolidate land security and hence increase in productivity and make farmers more responsible for the management of natural resources (Maxwell and Wiebe, 1999; Deininger and Binswanger, 1999). However, while land reform is deemed necessary, the experience in other parts of Africa demonstrates the need for flexibility in both the design and administration of new institutions (Hunter and Mabbs-Zeno, 1986). Superimposition of property rights over customary tenure systems through land registration and titling in much of Africa has often not had the intended impact (Atwood, 1990; Maxwell and Wiebe, 1999). It is argued that formal land title, especially under condition of low population density, is not necessarily the most cost-effective and desirable way of ensuring tenure security (Hunter and Mabbs-Zeno, 1986; Atwood, 1990; Deininger and Binswanger, 1999; Fortin, 2005). Deininger and Binswanger (1999) have suggested alternatives to formal land titling. These include awarding property rights to communities, which then decide on the most suitable tenure arrangements as well as encouraging long-term rentals and transferable leases, which could increase investment.

However, since land issues are of crucial importance to economic and social development, growth, poverty reduction and governance (Anon, 2004), implementation of land reforms require a careful and well implemented approach which places current land issues within the broader historical, political, economic and social context (Anon, 2004, Deininger and Binswanger, 1993; Maxwell and Wiebe, 1999; Ducourtieux et al., 2005).

In Ghana, land policy reforms must not only aim at land registration and titling of existing rights due to problems associated with cost and accessibility by poorer rural populations. In our study, it was found that land security does not only depend on what the precise rules and tenure arrangements are, but also on whether people have adequate access to relevant information (e.g. who should be involved in contract negotiation) as well as on adequate arrangements for conflict resolution. Hence, policy reforms in land tenure should aim at establishing institutions and structures with responsibility for land acquisition, administration and conflict resolution at the local level. Where these institutions and structures already exist, there is the need to strengthen them to make them more functional. Further study is however required to determine the value of different arrangements for making the system more transparent.

7.7. Conclusions

The study which used participatory approaches initially focused on developing soil fertility management innovations that meet the needs and circumstances of farmers. However, insights generated through continuous exploration throughout the study showed that our initial notion about soil fertility management was too narrow. What we initially conceived as 'soil fertility management' cannot be usefully separated from cropping systems, livelihood ambitions and land tenure relations.

The role of long-term rotational strategies such as those involving cassava and pigeonpea in soil fertility improvement appears not only to be related to beneficial effects of N contained in the incorporated biomass but also to other factors including mycorrhizal effects and reduction in weed incidence as a result of suppression of weeds by canopies of these crops. A further research is thus required to study the contributing role of mycorrhizal fungi on the observed residual effect of cassava cropping on soil fertility improvement. In as much as cassava/maize and pigeonpea/maize rotations appear to be more profitable due partly to the high yielding potential of cassava and pigeonpea, even on relatively less fertile fields, as well as the relatively low labour and input requirements of these crops, they appear to be less attractive to some sections of the farm population due to institutional bottlenecks such as market and land tenure.

Continuous exploration and diagnosis throughout the study period was essential for understanding the complexity of the farming system and allowed relevant issues to be taken on board as they emerged. The findings of this study are particularly relevant to refining agricultural research and educational policies to make them more relevant to serve the needs of farmers who are the ultimate users of agricultural innovation.

References

Anonymous, 2001. Sustainable Food Security for All by 2020 Conference, Bonn, Germany, 4 to 6 September 2001 (International Food Policy Research Institute, Washington, DC, 2001); www.ifpri.org/2020conference

Anonymous, 2004. EU land policy guidelines to support land tenure policy design in developing countries. Commission staff working document. Commission of the European Communities, Brussels.

Atwood, A. D., 1990. Land registration in Africa; the impact on agricultural production. World Development, 18: 659-671.

Chambers, R. and Jiggins, J., 1987. Agricultural research for resource-poor farmers. Part 1: transfer of technology and farming system research. Agricultural Administration and Extension, 27: 35-52.

Defoer, T., 2002. Learning about methodology development for integrated soil fertility management. Agricultural Systems, 73: 57-81.

de Jager, A., 2005. Participatory technology, policy and institutional development to address soil fertility degradation in Africa. Land Use Policy, 22: 57-66.

Deininger, K. and Binswanger, H. 1999. The Evolution of the World Bank's land policy: principles, experience and future challenges. The World Bank Research Observer, 14: 247-276

Ducourtieux, O., Laffort, J. R., and Sacklokam, S. 2005. Land policy and farming practices in Laos. Development and Change, 36: 499-526.

Fortin, E., 2005. Reforming land rights: The World Bank and the globalization of agriculture. Social and Legal Studies, 14: 147-177.

Gladwin, C.H., Peterson, J.S. and Mwale, A.C., 2002. The quality of science in participatory research: A case study from Eastern Zambia. World Development, 30: 523-543.

Hunter, J. and Mabbs-Zeno, C. 1986. African land tenure. Agricultural Administration, 23: 109-122.

Inter Academy Council (IAC), (2004). Realising the Promise and Potential of African Agriculture. Inter Academy Council, The Hague, 266 pp.

Johnson, N.L., Lilja, N., Ashby, A., 2003. Measuring the impact of user participation in agricultural and natural resource management research. Agricultural Systems, 78: 287-306.

McAuslan, P., 1998. Making law work: restructuring land relations in Africa. Development and Change 29: 525-552.

Maxwell, D. and Wiebe, K., 1999. Land tenure and food security: exploring the dynamic linkages. Development and Change 30: 825-849.

Migot-Adholla, S., Hazell, P., Blarel, B and Place, F. 1991. Indigenous land rights systems in Sub-Saharan Africa: A constraint on productivity? World Bank Economic Review, 5: 155-175.

Morford, S., Robinson, D., Mazzoni, F., Corbett, C. and Schaibrger, H. 2004. Participatory research in rural communities in transition: A case study of the Malaspina-Ucluelet Research Alliance. BC Journal of Ecosystems and Management, 5: 39-43. URL: www.forrex.org/jem/2004/vol5/no.2/art5.pdf

Offei, S.K. and Sakyi-Dawson, O., 2002. Technographic studies on cowpea as a private sector crop in Ghana. Report presented at an International Workshop on the 'Convergence of Sciences' project, 23–29 March 2002, Cotonou, on line available at http://www.dpw.wageningen-ur.nl/forum accessed on 12 September 2002.

Platteau, J-P., 1992. Land reform and structural adjustment in Sub-Saharan Africa. Rome: Food and Agricultural Organisation.

Roling, N., and van de Fliert, E., 1994. Transforming extension for sustainable agriculture: the case of integrated pest management in rice in Indonesia. Agriculture and Human Values, 11: 96-108.

Saïdou A., 2006. Converging strategies by farmers and scientists to improve soil fertility and enhance crop production. PhD thesis. Wageningen University, Wageningen.

Stoop, W. A and Hartig, T., 2005. Supporting Farmer Innovations: " Bridging the gap between scientific theory and the diverse farming practices of smallholder farmers". Knowledge and Learning Processes. www.forrex.org/jem assessed on 20 June 2006.

Tittonel, P., Vanlauwe, B., Leffelaar, P.A., Rowe, E.C. and Giller, K.E., 2005. Exploring diversity in soil fertility management of smallholder farms in western Kenya. I. Heterogeneity at region and farm scale. Agriculture, Ecosystem and Environment, 110: 149-165.

Zingore, S., 2006. Exploring diversity within smallholder farming systems in Zimbabwe: Nutrient use efficiencies and resource management strategies for crop production. PhD thesis. Wageningen University, Wageningen.

Summary

The role of agricultural science in innovation development in sub-Saharan Africa has been constrained by the adherence to the linear model of innovation. It is assumed that developing innovations jointly with farmers using their values, knowledge and expertise through negotiations will not only produce research outcomes that are appropriate but also at the same time contribute to changing the boundaries and conditions that affect the space for innovation and change. The original entry point for this study was how to optimise long-term rotation strategies to combat the problem of soil fertility decline in Wenchi, Ghana. However, as the study progressed over time, it was realised that what were originally interpreted as soil fertility management strategies were closely intertwined with wider issues such as cropping systems, livelihood aspirations and land tenure relations.

A diagnostic study was carried out to explore farmers' soil fertility management practices and their relevant social context with the purpose of grounding the subsequent action research in the needs of the local farming community. The study revealed an association between tenure insecurity among migrant farmers especially, and limited attention for regeneration of soil fertility. The native farmers who own land tend to use rotations involving long-duration crops such as cassava and pigeonpea to improve their soils. In contrast, migrants appear to depend mostly on short-term rental or sharecropping arrangements, which prevent them from using such long-term rotations. Instead, they rely more on rotations with short duration crops such as cowpea and groundnut to improve soil fertility. At the same time, however, migrants tend to crop the same piece of land to maize for two years in both the major and minor seasons in order to get the maximum from the land, thus mining the soil of nutrients. Due to this, the landowning natives often accuse the migrants of degrading their lands, which in turn makes them reluctant to rent land to migrants beyond two years. The migrants cite tenure insecurity and high cost of land rent as reasons for not investing in soil fertility regeneration. The natives do not trust that when they rent land to migrants for a longer period, they will take good care of it. The migrants on the other hand are afraid that when they invest in soil fertility, they will not be allowed to reap the full benefit.

We explored diversity among farm households in order to understand its relevance and implications for orienting action research aimed at combating soil fertility decline. The study revealed that historical, ethnic and gender dimensions of diversity provide additional insights in livelihood patterns and soil fertility management which are relevant for fine-tuning technical and social action research agendas. The earlier migrants (the Mossi, Lobis and Dagarbas) who migrated into Wenchi between 1940s and 1960s regard their stay in Wenchi as permanent and use cropping practices which to some extent can regenerate soil fertility. On the other hand, the later migrants (the Walas) who arrived in the 1990s regard their stay in Wenchi as temporal and use cropping practices which tend to mine the soil of nutrients. While native male farmers practice sole maize cropping, often rotating it with cassava or cowpea, native female farmers feel that they do not have access to production resources like inputs, cash, credit and labour needed for the cultivation of maize and cowpea. They also perceive the cultivation of these crops as risky farm enterprises due to the high susceptibility of maize and cowpea to drought and insect pests respectively. Female farmers therefore resort to the cultivation of crops such as cassava, yam, cocoyam and pigeonpea in complex intercropping systems. In terms of rotational strategies for regenerating soil fertility, no significant differences were found among the different wealth categories. However, relatively well-off farmers tend to make greater use of external inputs for maintaining soil fertility.

Five cowpea varieties were evaluated for grain yield, N_2-fixation, biomass production and their subsequent residual N effects on a succeeding maize crop. Cowpea grain yield ranged between 1.07 to 1.31 t ha^{-1} on researcher-managed fields and 1.11 to 1.39 t ha^{-1} on farmer-managed fields with no significant differences in yield among the different varieties. Using the ^{15}N natural abundance technique to estimate N_2-fixation, the proportion of N_2 fixed by the various cowpea varieties ranged from 61-77%. The amount of N_2 fixed by the various cowpea varieties also ranged between 32 kg N ha^{-1} with Ayiyi and 67 kg N ha^{-1} with Legon prolific. Maize grain yield after cowpea without application of mineral N fertiliser ranged between 0.76 t ha^{-1} with Asontem to 1.46 t ha^{-1} with Legon prolific on researcher-managed fields compared with 0.38 t ha^{-1} after maize, and 0.83 t ha^{-1} with IT-810D-1010 to 1.66 t ha^{-1} with Legon prolific compared with 0.25 t ha^{-1} after maize on farmer-managed fields. Cowpea variety IT810D-1010 was ranked by the farmers as the most preferred cowpea variety due to its white seed type, short-duration, ease of harvesting and good market value. Despite of the high leaf biomass production and high amount of N_2 fixed by Legon prolific, it was the least preferred variety by the farmers due to lower market price, late maturity, least potential cash income (due to the red mottled seed type) and difficulty in harvesting. Although farmers recognized the contribution of cowpea to soil fertility and yields of the subsequent maize crop, they did not consider this as an important criterion when selecting varieties for use in their own fields.

Experiments were conducted for two years under both researcher and farmer-managed conditions to evaluate various farmer-developed technical practices for regenerating soil fertility. Maize grain yield after the various cropping sequences without application of mineral N fertilizer ranged from 0.5 t ha^{-1} with continuous maize to 2.23 t ha^{-1} with pigeonpea cropping on farmer-managed plots compared with 0.38 t ha^{-1} after speargrass fallow, and from 1.40 t ha^{-1} with continuous maize to 3.00 t ha^{-1} with cassava cropping on researcher-managed plots compared with 0.96 t ha^{-1} after speargrass fallow. On the researcher-managed plots, application of 60 kg N ha^{-1} to the maize crop resulted in maize grain yields ranging between 2.13 t ha^{-1} with continuous maize cropping to 4.19 t ha^{-1} with mucuna-maize-mucuna cropping compared with 2.5 t ha^{-1} after speargrass fallow. Cassava/maize rotation was ranked as the most preferred rotation by the native farmers while the migrant farmers ranked cowpea/maize rotation as the most preferred rotation. Among the native farmers, the male farmers ranked cowpea/maize rotation as the second most preferred rotation while the female farmers ranked pigeonpea/maize as the second most preferred rotation. A simple financial analysis performed to evaluate the profitability of the various rotational sequences showed cassava/maize rotation to be the most profitable rotational sequence with about 235% return on investment when N fertiliser was not applied and 186% return on investment when N fertiliser was applied to the maize crop compared to the other rotations which made return on investment ranging from -22% with speargrass fallow/maize rotation to 129% with pigeonpea/maize rotation when N fertiliser was not applied to the maize crop and 29% with continuous maize to 98% with pigeonpea/maize rotation when N was applied to the maize crop.

An action research in the social realm was carried out to develop institutional arrangements beneficial for soil fertility. Initial efforts aimed at bringing stakeholders together in a platform to engage in a collaborative design of new arrangements were stranded mainly because conditions conducive for learning and negotiations were absent. Efforts to support experimentation with alternative arrangements initiated by individual landowners and tenant farmers too were also not very successful since the implementation of these arrangements ran into difficulties due to intra-family dynamics and ambiguities regarding land tenure. However, further investigations to find out how ambiguities could be tackled, revealed that the local actors themselves had taken initiatives to reduce ambiguities. This included increased used of written documents to secure and formalise contracts with its attendant service providers such as letter writers, commissioners of oaths and local institutions to deal with land related disputes at the local level. However, there is still considerable scope for further development of these self-organised innovations. The study stresses the need for continuous diagnosis and exploration in action research in order to steer research in a relevant direction.

Samenvatting

De rol van de landbouwwetenschappen in de ontwikkeling van innovaties in Afrika ten zuiden van de Sahara is beperkt geweest als gevolg van het vasthouden aan het lineaire innovatiemodel. In ons onderzoek gingen we er van uit dat het ontwikkelen van innovaties samen met boeren, gebruik makend van hun waarden, kennis en ervaring via een onderhandelingsproces, niet alleen zal leiden tot onderzoeksresultaten die voor boeren geschikt zijn, maar tevens zal bijdragen tot het veranderen van de omstandigheden en grenzen die de ruimte voor innovatie en verandering bepalen. Het oorspronkelijke vertrekpunt voor deze studie was de vraag hoe we lange-termijnrotaties van gewassen konden optimaliseren om het probleem van de afname van bodemvruchtbaarheid in Wenchi, Ghana, tegen te gaan. Maar gedurende de looptijd van het onderzoek realiseerden we ons dat datgene, wat we oorspronkelijk hadden geïnterpreteerd als strategieën om bodemvruchtbaarheid te beheren, nauw verstrengeld was met bredere thema's zoals landbouwsystemen, verwachtingen t.a.v. levensonderhoud, en landgebruiksrechten.

Een diagnostische studie werd uitgevoerd om te verkennen welke strategieën boeren gebruiken ten behoeve van bodemvruchtbaarheidsbeheer en om de relevante sociale context te begrijpen zodat we het daarop volgende actie-onderzoek beter konden funderen in de behoeften van de locale boerengemeenschap. De studie liet een verband zien tussen de onzekerheid van landgebruiksrechten van migranten-boeren en hun beperkte aandacht voor behoud en herstel van bodemvruchtbaarheid. De inheemse boeren die land bezitten gebruiken gewoonlijk gewasrotaties met gewassen die meer groeiseizoenen op het land blijven, zoals cassave en duivenerwt, om hun bodems te verbeteren. Migranten-boeren daarentegen maken gebruik van korte-termijn landgebruiksovereenkomsten (pacht, maar ook land-voor-werk-overeenkomsten), die het hun verhinderen zulke langere-termijnrotaties toe te passen. Ze maken daardoor meer gebruik van kortetermijnrotaties met koeienerwt en aardnoot om de bodemvruchtbaarheid te verbeteren. Maar tegelijkertijd hebben migranten de neiging om op hetzelfde stuk land twee jaar achtereen maïs te verbouwen in zowel het lange als korte regenseizoen, met als doel de maximale waarde uit het land te halen. Het gevolg is dat migranten de bodem uitmijnen. De inheemse landeigenaren beschuldigen op hun beurt vervolgens de migranten dat ze verantwoordelijk zijn voor landdegradatie. Om die reden zijn de landeigenaren erg aarzelend om land langer dan voor twee jaar uit te geven. De migranten op hun beurt noemen de onzekerheid van hun landgebruiksrechten en de hoge kosten om land te pachten als de voornaamste redenenen waarom ze niet investeren in herstel van bodemvruchtbaarheid. De inheemse landeigenaren vertrouwen er niet op dat migranten, wanneer die land voor een langere periode dan twee jaar zouden kunnen pachten, toch dat land goed zouden beheren, terwijl de migranten vrezen dat zij, wanneer ze investeren in bodemvruchtbaarheid, niet in staat zullen zijn de vruchten te plukken van hun eigen investering.

We deden onderzoek naar de diversiteit aan huishoudens om de betekenis en implicaties van deze relaties te kunnen begrijpen ten behoeve van daarop volgend actie-onderzoek naar strategieën om de afname van bodemvruchtbaarheid te bestrijden. Dit onderzoek liet zien dat historische, etnische en genderdimensies van diversiteit aanvullende inzichten opleveren in hun patronen van levensonderhoud en hun bodemvruchtbaarheidsbeheer. Deze verfijnde inzichten zijn van belang voor de agenda voor actie-onderzoek in het technische en het sociale domein. De vroegere migranten (Mossi, Lobis en Dagarbas), die naar Wenchi migreerden tussen de veertiger en zestiger jaren van de vorige eeuw, beschouwen hun verblijf in Wenchi als permanent. Ze gebruiken landbouwpraktijken die tot op zekere hoogte bodemvruchtbaarheid kunnen herstellen. De latere migranten (Walas), die in de negentiger jaren zich vestigden, beschouwen hun verblijf in Wenchi als van tijdelijke aard en hebben landbouwsystemen die de bodem uitmijnen. Bij de inheemse boeren praktiseren de mannen de teelt van maïs in monocultuur, dikwijls in rotatie met cassave of koeienerwt, terwijl de vrouwen het gevoel hebben dat ze geen toegang hebben tot middelen zoals kunstmest, pesticiden, krediet en arbeidskrachten die nodig zijn voor de teelt van maïs en koeienerwt. Ze zijn eveneens van mening dat de teelt van deze gewassen riskant is, doordat maïs en koeienerwt erg gevoelig zijn voor respectievelijk droogte en insectenplagen. De vrouwelijke boeren nemen hun toevlucht tot de teelt van gewassen zoals cassave, yam, taro (cocoyam) en duivenerwt in complexe mengteeltsystemen. Er bleken geen significante verschillen te bestaan tussen rijkere en armere boeren met betrekking tot strategieën voor vruchtwisseling om bodemvruchtbaarheid te herstellen De rijkere boeren bleken echter gemiddeld wel vaker gebruik te maken van externe inputs om de bodemvruchtbaarheid te handhaven.

Vijf rassen van koeienerwt werden geëvalueerd wat betreft opbrengst, stikstofbinding, bladproductie en de daaruit afgeleide effecten op de stikstofbeschikbaarheid voor maïs als volggewas. De opbrengst van koeienerwten varieerde van 1,07 tot 1,31 ton per hectare op proefvelden die door de onderzoeker werden beheerd, en van 1,11 tot 1,39 ton per hectare op proefvelden die door boeren werden beheerd. Er waren geen significante opbrengstverschillen tussen de rassen. Door gebruik te maken van de ^{15}N techniek in natuurlijke abundantie konden we vaststellen dat de verschillende rassen van koeienerwt voor 61-77% in hun stikstofbehoefte voorzagen via stikstofbinding. In absolute hoeveelheden uitgedrukt bleek de stikstofbinding van de verschillende rassen te variëren van 32 kg stikstof per hectare voor Ayiyi tot 67 kg stikstof per hectare voor Legon prolific. De maïsopbrengst na koeienerwt, zonder bemesting met stikstof, varieerde van 0,76 ton per hectare voor Asontem tot 1,46 ton per hectare voor Legon prolific in proefvelden die door de onderzoeker werden beheerd; en van 0,83 ton per hectare voor IT-810D-1010 tot 1,66 ton per hectare voor Legon prolific in proefvelden die door boeren werden beheerd. Ter vergelijking bleek de maïsopbrengst (in continuteelt) respectievelijk 0,38 en 0,25 ton per hectare te bedragen. De boeren gaven de voorkeur aan IT-810D-1010 vanwege de witte bonen, korte groeiperiode, oogstgemak en hoge marktprijs. Ondanks de hoge productie van bladmassa en de grote hoeveelheid gebonden luchtstikstof door Legon prolific was dit het door de boeren minst gewaardeerde ras vanwege de lage marktprijs, late rijping, rood-gestippelde bonen en grotere problemen bij het oogsten. Hoewel boeren de bijdrage van koeienerwt aan de bodemvruchtbaarheid en de opbrengst van maïs als volggewas onderkenden, beschouwden zij dit niet als een belangrijk criterium voor het uitkiezen van rassen voor eigen gebruik.

Gedurende twee jaar werden proeven uitgevoerd om de effectiviteit te kunnen beoordelen van door boeren ontwikkelde technieken om bodemvruchtbaarheid te herstellen. De opbrengst van maïs als volggewas in verschillende teeltsystemen zonder toepassing van stikstofkunstmest varieerde van 0,5 ton per hectare in de continue maïsteelt tot 2,23 ton per hectare in het teeltsysteem met duivenerwt in door boeren beheerde velden; en van 1,40 ton per hectare in de continue maïsteelt tot 3,0 ton per hectare in het teeltsysteem met cassave in de door de onderzoeker beheerde proefvelden. Maïsteelt op braakliggende velden met voorheen speergras leverden resp. 0,38 ton en 0,96 ton per hectare maïs op. In de door de onderzoeker beheerde proefvelden resulteerde de toepassing van 60 kg stikstofkunstmest per hectare in een aanzienlijke opbrengstverhoging van de maïs: tussen 2,13 ton per hectare voor continue maïs tot 4,19 ton per hectare voor een teeltsysteem met fluweelboon-mais-fluweelboon, en 2,5 ton per hectare in een braakgrond met vorheen speergras. De inheemse boeren gaven de voorkeur aan een vruchtwisseling tussen cassave en maïs, terwijl de migranten-boeren de grootste voorkeur hadden voor de vruchtwisseling tussen koeienerwt en maïs. Bij de inheemse boeren zetten mannen de rotatie tussen maïs en koeienerwt op de tweede plaats, terwijl de vrouwen de rotatie tussen duivenerwt en maïs op de tweede plaats zetten. Een eenvoudige economische analyse die werd uitgevoerd om de winstgevendheid van de verschillende teeltsystemen te kunnen beoordelen liet zien dat de rotatie van maïs en cassave het meest winstgevend was. De winst (return on investment) was 235% zonder en 186% met stikstofkunstmest toegediend aan de maïs. Voor de andere rotaties gold zonder bemesting een verlies van 22% (braakgrond met voorheen speergras waarop maïs werd geplant) tot een winst van 129% (rotatie duivenerwt en maïs), en met bemesting een winst van 29% (continue maïs) tot 98% (rotatie duivenerwt en maïs).

Actie-onderzoek in het sociale domein werd uitgevoerd om institutionele arrangementen te kunnen ontwikkelen die zouden bijdragen tot handhaven of herstel van bodemvruchtbaarheid. De eerste pogingen om de betrokken partijen in een gemeenschappelijke groep samen te brengen om van daaruit gezamenlijk nieuwe arrangementen te ontwikkelen mislukten, hoofdzakelijk doordat de omstandigheden die zouden moeten leiden tot leren en effectief onderhandelen afwezig waren. Pogingen om individuele experimenten met alternatieve landgebruikregels tussen inheemse en migranten-boeren uit te voeren waren eveneens weinig succesvol, doordat de uitvoering van de nieuwe afspraken tot problemen leidde door de onduidelijke machtsverhoudingen binnen de familie van landeigenaren, en door de dubbelzinnigheden en onbepaaldheden in het systeem van landgebruiksrechten. Nader onderzoek om vast te stellen hoe we deze dubbelzinnigheden en onbepaaldheden zouden kunnen oplossen liet zien dat de plaatselijke actoren reeds stappen hadden ondernomen om deze dubbelzinnigheden te verminderen. Deze initiatieven behelsden het gebruik van schriftelijke documenten om contracten te formaliseren en daardoor zekerder te stellen. Door het gebruik van schriftelijke contracten ontstaan nieuwe diensten, zoals documentopstellers, gevolmachtigden bij eden, en andere locale instituties om met landconflicten op plaatselijk niveau om te kunnen gaan. Maar er blijkt nog aanzienlijke ruimte te zijn voor verdere ontwikkelingen in deze zelf-georganiseerde innovaties. De studie benadrukt het belang van continue diagnose in actie-onderzoek om onderzoek in de meest relevante richtingen te sturen.

Appendix

THE CONVERGENCE OF SCIENCES PROGRAMME[1]

Background

This thesis is the outcome of a project within the programme "*Convergence of Sciences: inclusive technology innovation processes for better integrated crop and soil management*" (CoS). This programme takes off from the observation that West African farmers derive sub-optimal benefit from formal agricultural science. One important reason for the limited contribution of science to poverty alleviation is the conventional, often tacit, linear perspective on the role of science in innovation, i.e. that scientists first discover or reveal objectively true knowledge, applied scientists transform it into the best technical means to increase productivity and resource efficiency, extension then delivers these technical means to the 'ultimate users', and farmers adopt and diffuse the 'innovations'.

In order to find more efficient and effective models for agricultural technology development the CoS programme analysed participatory innovation processes. Efficient and effective are defined in terms of the inclusion of stakeholders in the research project, and of situating the research in the context of the needs and the opportunities of farmers. In this way stakeholders become the owners of the research process. Innovation is considered the emergent property of an interaction among different stakeholders in agricultural development. Depending on the situation, stakeholders might be village women engaged in a local experiment, but they might also comprise stakeholders such as researchers, farmers, (agri)-businessmen and local government agents.

To make science more beneficial for the rural poor, the CoS programme believes that convergence is needed in three dimensions: between natural and social scientists, between societal stakeholders (including farmers), and between institutions. Assumptions made by

[1] Hounkonnou, D., D.K. Kossou, T.W. Kuyper, C. Leeuwis, P. Richards, N.G. Röling, O.Sakyi-Dawson, and A. van Huis, 2006. Convergence of sciences: the management of agricultural research for small-scale farmers in Benin and Ghana. *Wageningen Journal of Life Sciences (NJAS)*, 53(3/4): 343-367.

CoS are that for research to make an impact in sub-Saharan Africa: most farmers have very small windows of opportunities, farmers are innovative, indigenous knowledge is important, there is a high pressure on natural resources, the market for selling surplus is limited, farmers have little political clout, government preys on farmers for revenue, and institutional and policy support is lacking. To allow '*ex-ante* impact assessment' and ensure that agricultural research is designed to suit the opportunities, conditions and preferences of resource-poor farmers, CoS pioneered a new context-method-outcome configuration[2] using methods of technography and diagnostic studies.

Technographic and diagnostic studies

The technographic studies explored the innovation landscape for six major crops. They were carried out by mixed teams of Beninese and Ghanaian PhD supervisors. The studies looked at the technological histories, markets, institutions, framework conditions, configurations of stakeholders, and other background factors. The main objective of these studies was to try and grasp the context for innovation in the countries in question, including appreciation of limiting as well as enabling factors.

The diagnostic studies were carried out by PhD students from Benin and Ghana. They focused in on groups of farmers in chosen localities, in response to the innovation opportunities defined during the technographic studies. The diagnostic studies tried to identify the type of agricultural research - targeting mechanisms - that would be needed to ensure that outcomes would be grounded in the opportunities and needs of these farmers. Firstly, that not only meant that research needed to be technically sound, but also that its outcomes would work in the context of the small farmers, taking into account issues such as the market, input provision, and transport availability. Secondly, the outcomes also needed to be appropriate in the context of local farming systems determined by issues such as land tenure, labour availability, and gender. Thirdly, farmers also need to be potentially interested in the outcomes taking into account their perceived opportunities, livelihood strategies, cultural inclinations, etc.

[2] See R. Pawson and N. Tilley, 1997. *Realistic evaluation*. London: Sage Publications.

The diagnostic studies led to the CoS researchers facilitating communities of practice of farmers, researchers, scientists from national research institutes, local administrators and local chiefs. The research was designed and conducted with farmer members of the local research groups. Their active involvement led to experiments being added, adapted or revised. It also made the researchers aware of the context in which the research was conducted. A full account of the diagnostic studies can be found in a special issue of NJAS[3].

Experimental work with farmers

After completing the diagnostic studies, the PhD students engaged in experiments with farmers on integrated pest and weed management, soil fertility, and crop genetic diversity, in each case also taking into account the institutional constraints to livelihoods. They focused on both experimental content and the design of agricultural research for development relevance. Experiments were designed and conducted together with groups of farmers, and involving all stakeholders relevant for the study. The aim was to focus on actual mechanisms of material transformation – control of pests, enhancement of soil fertility, buffering of seed systems – of direct relevance to poverty alleviation among poor or excluded farming groups. The ninth PhD student carried out comparative 'research on research' in order to formulate an interactive framework for agricultural science.

Project organization

All students were supervised by both natural and social scientists from the Netherlands and their home countries. In each country, the national coordinator was assisted by a working group from the various institutions that implemented the programme. A project steering committee of directors of the most relevant research and development organizations advised the programme. The CoS programme had a Scientific Coordination Committee of three persons, including the international coordinator from Wageningen University.

[3] Struik, P.C., and J.F. Wienk (Eds.), 2005. Diagnostic studies: a research phase in the Convergence of Sciences programme. *Wageningen Journal of Life Sciences (NJAS)*, 52 (3/4): 209-448.

CoS had two main donors: the Interdisciplinary Research and Education Fund (INREF) of the Wageningen University in the Netherlands and the Directorate General for International Cooperation (DGIS), Ministry of Foreign Affairs of the Netherlands. Other sponsors were the FAO Global IPM Facility (FAO/GIF), the Netherlands Organization for Scientific Research (NWO), the Wageningen Graduate School Production Ecology and Resource Conservation (PE&RC), the Technical Centre for Agricultural and Rural Cooperation (CTA or ACP-EU), and the Netherlands organization for international cooperation in higher education (NUFFIC). The total funds available to the project were about € 2.2 million.

Curriculum vitae

Samuel Adjei-Nsiah was born on the 17th of January, 1965 at Barekese in Ghana. After his primary school education, he proceeded to Konongo-Odumasi Secondary School, where he obtained the General Certificates of Education, Ordinary level (G.C.E., O Level) and Advanced level (G.C.E., A Level) in 1984 and 1986 respectively. From 1987-1991, he studied and obtained a Bachelor of Science degree (Honours) in Agriculture at the University of Science and Technology, Kumasi, Ghana. In 1996, he obtained a MPhil. degree in Crop Science at the University of Ghana, Legon. He worked as a Research Associate with the International Institute of Tropical Agriculture (IITA), West Africa Plantain Project between 1994 and 1999 where he was involved in research and training of Agricultural Extension Agents of the Ministry of Food and Agriculture in integrated crop management in Plantain. In 1999, he was appointed a Research Fellow at the University of Ghana Agricultural Research Centre at Kade. He was awarded the Wageningen University INREF-COS project Fellowship in 2002 to study for the award of PhD degree. His PhD research is entitled “Cropping systems, land tenure and social diversity in Wenchi, Ghana: implications for soil fertility management”.

List of Publications

Adjei-Nsiah, S., Kuyper, T.W., Abekoe, M.K. and Giller, K.E. 2006. Cassava improves soil fertility? Soil fertility management practices among smallholder farmers in the forest/savannah transitional agro-ecological zone of Ghana. *Field Crop Research*. Submitted.

Adjei-Nsiah, S., Kuyper, T.W., Leeuwis, C., Abekoe, M.K., Cobbina, J., Sakyi-Dawson, O. and Giller, K.E. 2006. Productivity, yield and N_2-fixation in cowpea varieties and their subsequent residual N effects on a succeeding maize crop: farmers' agronomic and social indicators. *Nutrient Cycling in Agroecosystems*. Submitted.

Adjei-Nsiah, S., Leeuwis, C., Giller, K.E. and Kuyper, T.W., 2006. Negotiation and experimentation towards alternative land tenure arrangement in Wenchi. The significance of ambiguity and self-organized institutional innovation. *Agriculture and Human Values*. Submitted.

Adjei-Nsiah, S. Saïdou, A., Dansou, K., Sakyi-Dawson, O. and Kuyper, T.W., 2006. Tenure security and soil fertility management: Case studies in Ghana and Benini. Colleque international "Les frontiers de la question foncière−At the frontier of land issues, 2006, May 17-19, Montpellier, France.

Adjei-Nsiah, S., Leeuwis, C., Sakyi-Dawson, O., Giller, K.E. and Kuyper, T.W. 2006. Exploring diversity among farmers for orienting inter-disciplinary action research on cropping system management in Wenchi, Ghana: the significance of time horizons. *International Journal of Agricultural Sustainability*. (in press)

Adjei-Nsiah, S., Afreh-Nuamah, K. and Brentu, F.C., 2006. Yield potential of four plantain cultivars under optimized growing conditions in Ghana. *Ghana Journal of Horticulture*. (in press).

Adjei-Nsiah, S., Leeuwis, C., Giller, K.E., Sakyi-Dawson, O., Cobbina, J., Kuyper, T.W., Abekoe, M. and Van Der Werf, W. 2004. Land tenure and differential soil fertility management among native and migrant farmers in Wenchi, Ghana: implications for inter-disciplinary action research. *NJAS-wageningen journal of life sciences* 52(3-4), 331-348.

Green, K. R., Afreh-Nuamah, K. and Adjei-Nsiah, S., 2001. Hot water produces healthy plantains. *Appropriate Technology*, 28 (1): 44-45.

Danso, W.O., Green, K.R., Adjei-Nsiah S., and Afreh-Nuamah K., 1999. Financial Appraisal of plantain sucker production in Ghana. *MusAfrica* 13:4-7.

Green, K.R., Mensah-Bonsu, A., Adjei-Nsiah S. and Afreh-Nuamah, K., 1998. Farmers' perception of integrated pest management strategies for plantain production in Ghana (C. Picq, E. Foure and E.A. Frison, eds). Proceedings of an International Conference on Banana and Food Security, Douala, Cameroun, 10-14 November, 1997, 697-705.

Mensah-Bonsu, A., Green K.R., Adjei-Nsiah, S., Anda, K. and Afreh-Nuamah, K., 1998. Economic analysis of integrated pest management strategies for plantain production in Ghana (C. Picq, E. Foure and E.A. Frison, eds). Proceedings of an International Symposium on Banana and Food Security, Douala, Cameroun, 10-14 November, 1997, 707-717.

Adjei-Nsiah, S., Dzietror, A., Ahiekpor E.S.K., Afreh-Nuamah, K., Ofori, I.K., and Hemeng, O.B., 1996. Effects of planting depth, plant population and planting depth on growth, lodging and yield of plantain (Musa AAB) in Ghana. *MusAfrica* 9: 9-11.

Schil, P.F. Afreh-Nuamah, K. and Adjei-Nsiah, S**.,** 1996. Yield potential of plantain under different management conditions in Ghana. MusAfrica 10: 32

PE&RC PhD Education Statement Form

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 22 credits (= 32 ECTS = 22 weeks of activities)

Review of Literature (4 credits)

- Cropping systems, land tenure and social diversity in Wenchi, Ghana: implications for soil fertility management (2002)

Writing of Project Proposal (5 credits)

- Cropping systems, land tenure and social diversity in Wenchi, Ghana: implications for soil fertility management (2002)

Post-Graduate Courses (2 credits)

- Basic Statistics (2006)
- Advanced Statistics (2006)

Deficiency, Refresh, Brush-up and General Courses (10 credits)

- Methods and Techniques of Sociological Field Research (2002)
- Agricultural Knowledge and Information System (2002)
- Participatory Methods (2002)
- Scientific Writing (2002)

PhD Discussion Groups (5 credits)

- Plant and Soil Interactions (2002)
- Ghana Science Association Biennial Conference (2003)
- Convergence of Sciences Working Group Discussions (2004/2005)

PE&RC Annual Meetings, Seminars and Introduction Days (0.7 credit)

- PE&RC annual meeting (2005)
- PE&RC weekend (2006)

International Symposia, Workshops and Conferences (4 credits)

- European Weed Research Society, 12th EWRS Congress (2002)
- Integrated Soil Fertility Management Training, Togo (2002)
- International Workshop on Multi-stakeholder processes, Wageningen (2002)
- Colloque international "At the frontier of land issues", Montpellier (2006)

Laboratory Training and Working Visits (1 credit)

- Techniques in Soil and Plant Analysis, Soil Science Department, University of Ghana, Legon (2003)

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