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Understanding and improving the adoption of soil fertility interventions at the forest margin in Ghana

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UNDERSTANDING AND IMPROVING THE ADOPTION OF SOIL FERTILITY INTERVENTIONS AT THE FOREST MARGIN IN GHANA

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ABSTRACT

The outputs of national and international soils research have not been widely adopted amongst smallholder farmers in sub-Saharan Africa despite increasing population pressure. The research presented in this thesis set out to understand the reasons for low uptake of research outputs in the forest and transition zones of southern Ghana where livelihoods are threatened by shortened bush fallow rotations, and to suggest ways of improving the process of technology development and dissemination.

Multiple factors influence the intensification of land management. The adoption of soils technologies is linked to the opportunity costs of land and labour, and farmers' broader livelihood strategies. Field based research was carried out at five field sites in Ghana to understand diversity in agricultural activities and access to resources amongst disaggregated groups of farmers. A Knowledge Based Systems approach was used to understand local knowledge of soil fertility management at the same field sites. This contributed to an understanding of farmer decision making and identified gaps in farmers' knowledge of soil management. This research was complemented by a case study which considered the generation and transmission of knowledge about cover crops within the Brong Ahafo region, and provided insights into the institutional setting of agricultural research and dissemination.

General reasons for low adoption of existing techniques to improve soil fertility management in Ghana are understood and are recognized by the Ghanaian government. They include the low value cost ratio of inorganic fertiliser for staple food crops, lack of availability of organic material and limitations within public sector extension services, within the context of a relatively low level of investment in soils research.

This research found that a more fundamental constraint was the lack of systematic consideration of farmers' circumstances in the development of soils technologies. As a consequence of diversity in agricultural practices and access to resources in southern Ghana, technologies were only appropriate to a limited number of crops and cropping patterns, and a limited number of farmers. The resource requirements for the majority of these technologies made them more appropriate to male farmers than female farmers. There was a lack of soils technologies directly relevant to women farmers and other marginalised groups.

To address this issue an integrated framework and a set of tools was produced to focus research and dissemination on farmers with different circumstances. Using the framework resource access amongst disaggregated groups of farmers is compared with information on the requirements for different potential technologies to be effective. This helps identify the criteria which technologies must satisfy to be adopted by different groups of farmers and can be used to evaluate the potential impact of research outputs on farmers with different circumstances. Research resources can then be used effectively, and research outputs can be targeted at farmers with different circumstances. Where there are no technologies available for a particular group of farmers policy interventions may be appropriate.

The research also suggested that increasing farmer participation in the design of soil fertility management technologies in Ghana could contribute to the development of outputs appropriate to farmers with diverse sets of resource endowments. When used in conjunction with participatory technology development, the framework and tools could ensure that research outputs were widely relevant beyond the limited number of farmers that participate in on-farm research.

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ACRONYMS

AEA	Agricultural Extension Agent
ARI	Animal Research Institute
CGIAR	Consultative Group on International Agricultural Research
CIEPCA	Cover Crop Information and Seed Exchange Centre for Africa
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research
DFID	Department for International Development
EPHTA	Ecoregional Program for the Humid and Sub-humid Tropics of Sub-Saharan Africa
FORIG	Forestry Research Institute of Ghana
GTZ	German Technical Cooperation
ICRAF	International Centre for in Research in Agroforestry (World Agroforestry Centre)
IFCSP	Integrated Food Crop Systems Project
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
MOFA	Ministry of Food and Agriculture, Ghana
NGO	Non Governmental Organisation
PRA	Participatory Rural Appraisal
RELC	Research and Extension Linkage Committee
SARI	Savanna Agricultural Research Institute
SFSP	Sedentary Farming Systems Project
SRI	Soils Research Institute

1 INTRODUCTION

Soil fertility depletion on smallholder farms has been heralded as the fundamental biophysical root cause for declining per capita food production in Africa (Sanchez *et al.*, 1997). Although pressure on agricultural land has been increasing and accompanied by shorter fallows and soil fertility decline, it has generally been agreed that the outputs of research by national and international research organisations have not been widely adopted despite significant research investment (Bationo *et al.*, 1998; Donovan and Casey, 1998; Barrett *et al.*, 2002). Although consumption of inorganic fertiliser in sub-Saharan Africa has increased significantly since the 1970s, it remains very low compared to other regions of the world with much variation between years and between countries (Naseem and Kelly, 1999). Alley cropping has received a lot of research attention in Africa, but has had very low rates of adoption (Attah-Krah, 1995; Nelson *et al.*, 1998; Kanmegne and Degrande, 2000). It is now realised that its specific resource requirements limit its potential to a very narrow range of farmers (Sanchez, 1995).

Short term improved fallows have been considered a suitable replacement for natural fallow systems in the humid and sub-humid tropics and research in this area has increased since the 1980s (Sanchez, 1999; Szott *et al.*, 1999). In Eastern Zambia improved fallows, particularly those with *Sesbania sesban*, have increased maize yields significantly, and by the year 2000, 10 000 farmers were estimated to be experimenting with them (Kwesiga *et al.*, 1999; Franzel *et al.*, 2002c). Nevertheless, despite enthusiasm and farmer experimentation with leguminous species in many African countries, and some pockets of adoption, large scale adoption over wide areas remains elusive (e.g. Douthwaite *et al.*, 2002; Franzel *et al.*, 2002a).

In the south of Ghana, crop yields are widely recognised by both farmers and researchers to have declined and this is attributed to increasing population pressure and the shortening of fallow periods without the use of alternative soil management practices (Amanor, 1996; MOFA, 1998). Ghana has produced a National Soil Fertility Management Action Plan which recognises the low level of farmer adoption of soil fertility management technologies in all regions of Ghana (MOFA, 1998). Other reviews of soil fertility management acknowledge the low levels of inorganic fertiliser use within Ghana as a whole, and the limited use of low external input alternatives to natural fallows in the south of the country (Bonsu *et al.*, 1996; Quansah 1999).

Ghana's national policy framework, Ghana Vision 2020, has the objective of bringing Ghana to the status of a middle income country by the year 2020. Within this framework, the Ministry of Food and Agriculture is required to increase the agricultural sector's performance from the annual growth rate of 2 – 3% (1990 – 1997) to around 6% (MOFA, 1999). Improving access to technology for sustainable natural resource management is presented as one means of achieving this goal in the Ministry of Food and Agriculture's Accelerated Agricultural Growth and Development Strategy. Ameliorating the decline in soil fertility through intensification of land use using soil and water conservation practices and integrated nutrient management systems is outlined as a priority (MOFA, 1999).

1.1 Research objectives

The objective of the research was to develop an understanding of why there had been low adoption of outputs from research on soil fertility despite an apparent need to ameliorate soil conditions to sustain crop yields, and the technical success of interventions generated through research.

The central hypothesis was that low adoption occurs for two major reasons:

- Interventions generated through research do not address farmers' priorities or are not compatible with their circumstances.
- Research results are not effectively transmitted to farmers. This involves the way interventions are presented to farmers, the effectiveness of extension and the linkages between research and extension.

The relative importance of these constraints and the potential means to alleviate them were explored in this research.

The research focused on land based livelihoods at the forest margin in southern Ghana where livelihoods are diverse and complex, and threatened by shortening of bush-fallow rotations. Five field sites were chosen which differed in terms of natural resource endowments, population density and market access. The research started out by developing an understanding of agricultural activities and access to resources for crop production amongst disaggregated groups of the population at each site. Farmers' local knowledge of soil fertility management was elicited using a formal method for eliciting and representing local knowledge. This provided a context in which to evaluate the relevance of soil fertility research outputs produced for farmers in Ghana and the extent to which they had been successfully disseminated. This research was complemented by a case study which considered the generation and transmission of knowledge about cover crops within the Brong Ahafo

region, and provided insights into the institutional setting of agricultural research and dissemination. A framework linking rural livelihoods and agricultural research was then developed to address the issues raised by the improved understanding of the reasons for lack of adoption of soils research outputs.

The research involved systematic consideration of the following topics:

- Farmers' soil management strategies and their perceptions of soil fertility.
- The impact of location and social differences on farmers' access to productive resources for the intensification of agriculture.
- The impact of socio-economic circumstances including access to land, labour, information, markets and finance on farmers' soil management strategies.
- Knowledge flow between soils research and extension, and the means used to disseminate soil fertility management practices.

The way that the research is presented in this thesis is outlined below.

1.2 Overview of thesis layout

The thesis is presented in seven chapters. Following this introduction, there is a chapter reviewing research and extension related to soil fertility. This is followed by three chapters detailing farmers' livelihoods, their agro-ecological knowledge and a case study of knowledge flows related to a soil fertility technology. The sixth chapter presents a framework for integrating research and dissemination and is followed by a final set of conclusions and recommendations.

The following chapter, Chapter 2, provides the context for the research by reviewing and discussing the conditions under which intensification of soil fertility management takes place. It presents two case studies of technologies and their adoption, and summarises what soil fertility management research has been carried out in Ghana, extended to farmers, and adopted by them.

In Chapter 3 the livelihoods of farmers belonging to different social groups at five field sites at the forest margin in Ghana are compared and contrasted, and factors relevant to the adoption of soils technologies are discussed. In Chapter 4 farmers' knowledge of soil fertility management at the same sites is presented, and differences between farmers' knowledge and their actual soil fertility practices are discussed. In Chapter 5 the results of a case study looking at knowledge generation and exchange in recent cover crop research in the Brong Ahafo region is presented.

Chapter 6 builds on the results of the previous chapters and presents an integrated framework for linking agricultural research to rural livelihoods and developing appropriate soils technologies targeted at farmers with complex sets of resource endowments. Chapter 7 presents the final conclusions and recommendations from the research.

2 SUCCESSES AND FAILURES IN THE ADOPTION OF SOIL FERTILITY RESEARCH OUTPUTS

High external input green revolution technologies have been successful in raising crop yields but their success has been less apparent in sub-Saharan Africa than in Asia and Latin America (Weischet and Caviedes, 1993). Despite substantial research investment in low external input technologies, there is widespread agreement that technologies designed to improve soil fertility management, developed by national and international research institutions, have not been widely adopted by farmers in developing countries, particularly in sub-Saharan Africa (Bationo *et al.*, 1998; Donovan and Casey, 1998; Barrett *et al.*, 2002). This chapter considers first the conditions under which agricultural intensification occurs, and then explores the adoption of two particular soil fertility technologies in detail to learn more about the factors which have influenced their adoption or lack of adoption. This involves two case studies of soil fertility technologies that have received substantial research attention: alley cropping and cover crops. The chapter concludes by taking a geographical focus in considering which soil fertility research outputs have been developed and disseminated in the forest margin zone of Ghana.

2.1 Agricultural development and the intensification of land management

Agricultural intensification has been defined as 'increased value of net output per hectare through increased average inputs of labour or capital per unit of land' (Tiffen *et al.*, 1994). It therefore involves substituting land for labour and/or capital to increase crop yields or other outputs from a single unit of land. The conditions under which agricultural development and investment in soil fertility are understood to take place are reviewed in this section.

2.1.1 Population growth

Population pressure has long been postulated as a key factor leading to changes in land use. Malthus (1798) saw increasing population pressure as leading to land degradation whereas Boserup (1965) saw it as a stimulus to the intensification of agriculture.

Boserup (1965) sketched out three broad pathways for agricultural development. Broadly speaking, these can be loosely interpreted as capital led intensification, labour led

intensification and agricultural stagnation accompanied by out-migration. With capital led agricultural development population growth is accompanied by the use of improved agricultural technologies and integration of the rural economy into urban markets. In labour led intensification, integration of the agricultural economy into urban markets may not occur and agricultural technology development relies more on labour intensive inputs, and less on capital intensive ones. Land productivity may therefore increase, but labour productivity is likely to decrease. Where market integration does not occur, the agricultural economy stagnates, the population remains poor and out-migration occurs.

Since Boserup (1965), key factors in addition to population density which contribute to agricultural development and investment in soil fertility have been outlined in more detail. Agricultural development pathways have been sketched out drawing on available empirical evidence and more sophisticated models have been developed in an attempt to guide national policy makers. In the remainder of section 2.1 the models of agricultural intensification outlined by Ruttan (1998) are described. The different factors that influence agricultural development and more particularly investment in land management are outlined. Some examples of agricultural intensification are then discussed.

2.1.2 Models of agricultural development

Ruttan (1998) provides six detailed explanatory models of agricultural development (Table 2.1). Underlying all the models is an assumption that either increases in population or else market demand for agricultural products makes increasing production desirable. Whilst land is still abundant, increases in production are brought about by cultivating larger areas: agricultural extensification (the Frontier model). Once expansion is no longer possible then intensification occurs. In this context, it is necessary to recall that land is not homogeneous, at village as well as regional level. Differences in the productivity and desirability of land for cultivation in sub-Saharan Africa are influenced by moisture availability, distance from the homestead, ease of clearing, workability of the soil, stone content, slope and the presence of pests etc. (Levi and Havinden, 1982). Furthermore, differences in land distribution and tenure arrangements cause differential access to land amongst farmers. The availability of some types of land, for some people, may reach a premium at the same time as land remains abundant for others. Land intensification is therefore a non-uniform process. In addition to these considerations, and as Boserup (1965) points out, even where land is abundant and labour seemingly under-utilised, seasonal labour bottlenecks can limit the area under cultivation, particularly in rain fed agriculture.

In Ruttan's models the pathway which agricultural intensification takes is dependent on labour availability, the development and diffusion of agricultural knowledge and technologies and the influence of the non-agricultural sector. Agricultural technology joins land, labour and capital as a key commodity in agricultural development. Ruttan's Conservation model is primarily labour led where productivity increases at a modest rate due to the use of low external input technologies. The Diffusion model is primarily technology led. The introduction of new crops and varieties from other regions of the world has led to large gains in agricultural productivity in the past, but incorrect assumptions of large similarities in different contexts has produced more limited success more recently.

Ruttan's remaining three models attempt to explain how agricultural development takes place once rural livelihoods become more integrated into urban economies which create a demand for agricultural commodities and are able to supply capital and knowledge intensive technology inputs. The Urban-Industrial impact model attempts to explain how industrial development can provide a market for agricultural products, supply agriculture with industrial inputs and at the same time draw off surplus labour so that rural incomes improve. In the High Payoff input model agricultural research institutes play a role in supplying farmers with new knowledge and technologies. In the Induced innovation model Ruttan and Hayami (1998) attempt to explain how agricultural research can respond to demands from producers for new agricultural technologies through appropriate mechanisms and in the right policy environment.

Ruttan's models become increasingly complex once rural livelihoods become integrated into urban economies. Population pressure is no longer an adequate stimulus for increasing agricultural production when non-agricultural activities and migration become available options. Calculating the opportunity costs of labour and capital becomes more complicated once these can be diverted to activities in the non-agricultural sector. A multitude of factors influence the profitability of investing labour and capital in agriculture and these are examined in the next section. Requirements of demand driven agricultural technology development (the Induced innovation model) are prioritization of the agricultural sector by national policy makers and the ability of small-scale farmers to influence the allocation of resources for agricultural development. However, these factors and real democratic representation are conditions that are not frequently found, particularly in developing countries.

Table 2.1 Models of agricultural development (based on Ruttan, 1998; Ruttan and Hayami 1998)

Model	Mechanism for increases in agricultural production	Conditions under which model is successful	Examples
Frontier model	Opening up of new land	Abundant land is available for agricultural expansion.	Historically the dominant means of increases in production, now no longer possible in South-East Asia and awaiting control of pests and diseases or methods of increasing the productivity of problem soils in Africa and parts of Latin America.
Conservation model	Increasingly complex land and labour intensive cropping systems using labour intensive capital formation (e.g. for drainage and irrigation) and low external input technologies (e.g. production and use of organic manure).	There is a limited supply of land and capital but abundant labour.	The only option for much of the world's farmers until well into the 20th century. Development of wet–rice culture systems in East and South-east Asia and integrated crop livestock husbandry in 18th and 19th century Europe. China in the late 1950s and early 1960s. Agricultural production can increase at about 1% per annum over extended periods.
Diffusion model	More effective dissemination of available technical knowledge among farmers and among regions.	Available technical knowledge is widely applicable in different contexts.	A major source of productivity growth even in premodern societies through the diffusion of better husbandry practices. The introduction of new crops and animals from different regions of the world took place in the 15th to 19th centuries. Agricultural development strategies based on this model in lesser developed countries in the 1950s were less successful in increasing agricultural growth.
Urban-industrial impact model	Industrial development stimulates demand for agricultural products and hence development, at the same time as supplying industrial inputs to the agricultural sector and drawing off surplus labour.	Industrial development in the non-agricultural sector. A strong non-farm labour market is necessary for improved incomes for the rural population.	This model was used to explain geographic differences in performance in regions with and without development of an industrial urban economy in the U.S. It can explain geographic variations in the intensity of farming systems in environmentally similar areas. It is now relevant to less developed regions of highly industrialised countries and lagging regions of more rapidly developing countries.
High payoff input model	New high payoff inputs produced by public and private sector research institutions are adopted by farmers.	Public and private sector research institutions are capable of producing new technical knowledge, the industrial sector is able to develop, produce and market new technical inputs and farmers have the capacity to acquire the new knowledge and inputs and use them effectively.	High Yielding Varieties of wheat and rice developed in Mexico and the Philippines in the 1950s and 1960s which together with associated technical inputs and management practices spread amongst farmers in Asia and Latin America.
Induced innovation model	Market demand for new agricultural technologies stimulates their production. General progress in science and technology also contribute to the supply of technologies available.	Incentives exist at all levels to induce the development of new and appropriate technologies. Responsiveness by individuals and institutions in public sector research may be induced by e.g. professional standards, and in the private sector by profits from the sale of new technology (such as machinery). Investments in infrastructure and education may be necessary to induce adoption by rural producers. Administrators and policy makers must have incentives for making public sector investments. Politically effective local and regional farmers' organisations may be necessary.	Agricultural production in the USA and Japan

2.1.3 Factors influencing investment in soil fertility

Scoones and Toulmin (1999) have examined case studies of agricultural intensification and investment in soil fertility management in areas of sub-Saharan Africa. They outline biophysical, socio-economic, policy and institutional factors which influence intensification. Biophysical factors, namely rainfall and soils, form the parameters within which agricultural intensification takes place. Socio-economic conditions, which are influenced by institutions and policies, provide incentives for investment. Whether or not farmers invest as land becomes scarce depends on the prices of the different production factors and outputs as well as farmers' broader livelihood strategies. No single factor can explain decisions about investment in agriculture (Table 2.2). Due to differing levels of resource endowments, farmers' strategies for investment in land vary greatly amongst settings, amongst individual farmers and amongst different types of land on a single farm. Agricultural intensification is a complex process, and time and location specific.

The availability of land and the opportunity cost of labour are important factors in determining farmers' soil management strategies. Much soil fertility research assumes that agricultural intensification is inherently desirable due to land scarcity or declining fallow periods in bush fallow cultivation. It may well underestimate farmers' adaptations to decreasing land availability and utilisation of variability within the landscape.

More importantly, many soil management technologies produced by research involve greater inputs of either labour or capital than farmers' standard practice. The cash constrained nature of rural livelihoods is perhaps more readily accepted than labour constraints. Levi and Havinden (1982) suggest reasons why labour use is inherently difficult to measure. Activities cannot always be strictly divided into work and leisure. Some tasks, such as planting, must by necessity be carried out at particular times. Seasonal labour demand may make the subjective valuation of labour for the same task variable depending on the time of year. The unpleasantness of the task, the weather, and health and nutrition throughout the year influence work input, and experience, motivation and managerial ability all influence work output. There is a strong gender division of labour with women and men doing different agricultural and non-agricultural tasks. The individual who must invest additional labour in a certain task, may not, therefore, be the one to reap the benefits. Furthermore, farmers do not necessarily concentrate on optimising production, but invest labour in insurance strategies, such as the cultivation of low value crops such as cassava, in the event of crop failure.

Table 2.2 Factors influencing the intensification of agriculture in sub-Saharan Africa (based on Scoones and Toulmin, 1999)

Type of factor	Influence on soil fertility management
Biophysical	
Climate	Higher rainfall is generally associated with higher population density (but is not the only determinant). Where there is no irrigation, low rainfall is often associated with low population density, low input-low output farming systems which rely on fallowing and animal manure. Where rainfall is highly variable and combined with high fertiliser prices and limited cash crop opportunities agricultural growth will stagnate even if land is under pressure. High rainfall is neither necessary nor sufficient for maintenance of soil fertility where limits to the recycling of nutrients in the system have been reached.
Soils	The current status and trends in soil structure and nutrient management depend on the history of land use. Soils with high inherent fertility can lose their quality and organic matter and are vulnerable to erosion on slopes in areas where land has been settled and farmed for generations. The sands and gravels of the Sahel lose their initial fertility rapidly on cultivation and sustaining and increasing crop yields is dependant on organic and inorganic materials to improve water holding capacity and provide soil nutrients. In many areas where land has been cropped for generations and fallow has disappeared shortages of soil nutrients constitute a growing constraint which can only be partially addressed by nutrient recycling in the system. Specific localities may face shortages of particular nutrients such as zinc and sulphur in addition to nitrogen, phosphorous and potassium. Low cation exchange capacities are a problem in many tropical soils and an impediment to the efficient use of inorganic fertiliser. Variability in soils is used by farmers. Sometimes patches of higher value soils are created over time through many years of investment. Areas of soil with higher potential are often used to maximise cash returns and receive a concentration of labour and nutrients. Using upland and lowland soils and a diversity of crops helps spread the risk of crop failure and spreads labour over different seasons. Investment in soil fertility can be viewed in a historical context. Farming systems develop in response to external circumstances and depend on the anticipated returns and the other options available although inherent fertility is a consideration.
Crops and livestock	Cash cropping is often associated with investment in soil management. Grain crops are sources of cash for many farmers but their lower value/high bulk characteristics makes them less attractive to transport over long distances. Food crops may receive residual nutrients in cash crop areas. Crop livestock interactions are often important for maintaining soil fertility. Livestock systems are modified as grazing areas are reduced although the incentive to intensify production depends on access to livestock capital and labour. In some areas, livestock are kept as part of the family farm, whereas in others they are kept by specialist herders from a different ethnic group. Farmers' means of gaining manure is variable from place to place.

Table 2.2 continued

Socio-economic	Influence on soil fertility management
Population density	High population density is often associated with more intensive recycling of nutrients. In low population density areas labour limits the extent of soil fertility operations and investment may be restricted to certain fields. Where land becomes scarcer the opportunity cost of labour determines the extent to which increased investment in soil fertility takes place. Rising population density generates more opportunities for economic diversification within the rural sector, but economic growth is likely to be limited where based on local incomes alone. Integration with external markets for cash crops is therefore important.
Access to markets	Access to markets determines opportunities for the sale of cash crops, purchase of inputs, and off-farm incomes and is therefore critically important. Where there is limited market development, few opportunities for the sale of cash crops and limited access to, or highly priced, fertilisers, the intensification process may become blocked.
Broader livelihood strategies	Farmers' decisions about soil fertility management are made within the context of other broader farming and livelihood decisions and the allocation of resources including capital and labour will be made in consideration of the perceived returns and risks to different options.
Institutional	
Macro-economic policy	Structural adjustment programmes have influenced decisions about soil fertility through liberalisation of crop prices and input supply, abolition of subsidies and distribution systems for fertilisers and other inputs, and currency devaluation. In most cases structural adjustment has led to reduced use and access to fertiliser and closure of programmes aimed at widening knowledge and use of fertilisers. Value: cost ratios for maize and fertiliser have decreased in consequence.
Marketing structures	Parastatal companies supporting cash crops through the provision of a market, input supply, research and extension activities and credit supply can be a significant positive influence on agricultural investment, particularly in areas with little infrastructural development. This may have greater impact on poorer farmers with limited market opportunities.
Political and other events	Historical events may influence patterns of settlement and farming e.g. the surprisingly high population density and level of market orientation in the Kano close settled zone in Nigeria (Harris, 1996) which receives relatively low rainfall and has few fertile soils. Major upheavals due to political and other events can influence the stability of farming communities and their sense of security e.g. villagisation and de-villagisation in parts of Ethiopia, the *ujamaa* campaign in Tanzania, the conflict and genocide in Rwanda, drought in Zimbabwe. These events disrupt patterns of production and sources of income and may significantly shift the expected returns from farming and investment in it.
Land tenure	Title to land may be less important than underlying security of user rights which are often assured under customary systems of tenure. Changes in the land tenure situation can lead to environmentally undesirable practices.

Assessing seasonal labour requirements, and understanding the gender division of labour is relatively straightforward using quick participatory methods (e.g. Werner, 1993; Van Veldhuizen *et al.*, 1997). It is more difficult to estimate overall changes in labour requirements resulting from the use of new technologies. Some methods are available for this. Participatory budgeting exercises can suggest changes in resource requirements within a single farm enterprise (Galpin *et al.*, 2000; Dorward *et al.*, 2003). However, more detailed appraisal would be required to gauge whether changes to labour requirements in one farm enterprise were compatible with overall labour available to all farm and non-farm activities Furthermore, the labour required for a particular task may be viewed differently depending on how well it can be integrated into overall farming and non-farming activities and unplanned contingencies. In addition to the problems faced attempting to measure agricultural labour, establishing what the opportunity costs of labour are becomes complex once rural populations become integrated into larger economies. This is complex even for one individual, but in addition, exchanges between resident and non-resident household members may make calculating the perceived benefits of additional labour investment even more difficult.

2.1.4 Examples of agricultural intensification

Examples of population growth leading to agricultural intensification and better environmental management have been found, and are discussed below, but there are doubts as to whether this is the usual trend in sub-Saharan Africa (Boyd and Slaymaker, 2001; Drechsel *et al.*, 2001). Karshenas (2001) has argued on a very broad continent-wide scale, that differences in the development of the agricultural sector in sub-Saharan Africa and Asia stem in part from differences in the opportunity cost of labour. Sub-Saharan Africa and Asia have followed broadly similar strategies of development since independence but with different results. The agrarian structures of the two continents are different and one of the main differences stems from the labour constrained nature of economies in sub-Saharan Africa in comparison to the labour surplus economies of Asia.

Historically in Asia there has been a relatively small class of land owners and a high number of agricultural labourers (Karshenas, 2001). In contrast in Africa, where access to land is through indigenous institutions where membership of a community provides land use rights and family members provide the main source of labour, there is little surplus agricultural wage labour. Surplus wage labour in Asia has provided the industrial sector with cheap labour at the same time as enabling the agricultural sector to provide a cheap source of food and raw materials for growth in other sectors of the economy. In contrast, in the labour constrained economies of sub-Saharan Africa movement of labour from the agricultural to the non-

agricultural sectors has increased the cost of food for non-agricultural workers (Karshenas, 2001). Complimentary growth in the agricultural and industrial sectors and a strong non-farm labour market suggests that Ruttan's (1998) Urban-Industrial impact model of agricultural development was relevant to agricultural growth in Asia, although the success of High Yielding Varieties (HYV) which has been explained by the High Payoff input model is also relevant.

A second implication of low population densities has been the high transaction costs for small farmers (Karshenas 2001). Marketing boards have served to aid agricultural producers in remote areas in African countries and to reduce the cost of food for urban consumers. However they have not encouraged agricultural growth in more optimal rural areas with better infrastructural development, or aided greater integration of remote areas into the main economy. Low population density and the greater limitations of the natural resource base in sub-Saharan Africa as compared to Asia also result in higher investment requirements in agriculture. Insufficient levels of investment have resulted in a lack of technologies suitable for the soil and climate conditions of sub-Saharan Africa that can be adopted by small-scale food producers. Furthermore, Asian economies have benefited from more diversified export markets which have enabled them to better withstand negative terms of trade (Karshenas, 2001).

Karshenas's (2001) theories also lend themselves to Boserup's (1965) hypothesis in that higher population densities helped to sustain agricultural growth in Asia. On a smaller scale agricultural intensification has taken place in conjunction with increasing population density in the case of Machakos district in Kenya (Tiffen *et al.*, 1994). Agricultural development has taken place in conjunction with growth and diversification of the local economy. The area is well integrated into regional and international markets. High population densities have created increased food demand and stimulated the necessary infrastructural improvements for efficient marketing making farming more profitable than alternative off-farm sources of income. There has been significant investment in research and extension activities in the district from a multiplicity of sources and promotional agencies.

Agricultural intensification has also occurred under conditions of high population density in the Kano Close-Settled Zone in semi-arid Nigeria. Harris (1996) states that high labour availability coupled with the integration of crops and livestock have been the key to successful intensification. High labour inputs are required for stall feeding in the wet season and transportation of manure to the fields. Although high labour availability may be the key, Harris (1996) does not elucidate how the opportunity costs of labour are different and

favourable for farming in this area, compared to other semi-arid areas of high population density.

2.2 Successes and failures in the adoption of soil fertility interventions

This section will consider some of the reasons for the low adoption of outputs from soil fertility research and development activities. It focuses on experiences with two complex technologies, alley cropping and cover crops. The need for appropriate research and development and the multiplicity of factors that are likely to influence adoption of complex technologies, in comparison with relatively simple agricultural interventions such as the adoption of improved varieties and the use of inorganic fertiliser, has been noted by Franzel *et al.* (2001). Alley cropping and cover crops are two technologies that have met with varying degrees of success and illustrate well the different factors that influence farmer adoption.

Swinkels and Franzel (1997) suggest a framework for assessing the adoption potential of agroforestry practices which could also potentially be applied to other complex technologies (Table 2.3). Adoption potential is defined as 'the likelihood of uptake of a new technology or practice when required information and material are made available to the farmer (Franzel *et al.*, 2001). The framework goes beyond an assessment of the biophysical performance of the technology, and includes in addition its feasibility, profitability and acceptability to farmers. Feasibility is determined by whether the farmer is able to manage the technology and has sufficient access to information and resources to do so. Profitability assesses whether the financial and other benefits of the technology are higher than for alternative possibilities. It includes consideration of the profitability of the different crops, their basal yield and the opportunity cost of labour. Acceptability refers to whether a farmer is likely to want to use a technology, whether the advantages are perceived as greater than the disadvantages. Over and above profitability, acceptability may relate to farmers' perception of soil fertility as a problem, their past investment in soil fertility, access to off-farm income, the level of risk, the suitability to accepted gender roles, whether the technology is culturally acceptable and whether it is compatible with other activities (Swinkels and Franzel, 1997).

Table 2.3 Framework for assessing the adoption potential of soil fertility management technologies (adapted from Franzel, 1999)

Characteristic	Factors to consider
Feasibility	Access to information
	Institutional support
	Access to resources
	Labour constraints
	Previous experience with aspects of the technology
Profitability	Profitability of different crops
	Basal yield of crops
	Opportunity cost of labour
Acceptability	Perception of soil fertility as a problem
	Past investment in soil fertility
	Current soil fertility practices
	Economic importance of current cropping practices as part of livelihood strategy
	Access to off-farm income
	Riskiness of technology
	Suitability to gender roles
	Cultural acceptability
	Compatibility with other activities
	Influence of farmer's wealth level
	Influence of farmer's gender

2.2.1 Alley cropping

Alley cropping[1] is an agroforestry practice in which field crops are grown in alleys formed by hedgerows of trees or shrubs, preferably nitrogen-fixing species. The hedgerows are periodically pruned during cropping to reduce competition with crops for light, nutrients and moisture. Prunings may be used to add organic matter to the soil or fed to livestock (Kang *et al.*, 1999). Alley cropping was designed primarily to improve soil fertility and to offer an alternative to bush fallow cultivation. The alleys are cropped every year and the hedgerows are intended to eliminate the need for a fallow period. Deep rooting trees are able to capture and recycle nutrients leached from the upper soil layers (Rowe *et al.*, 2001). Other potential benefits of alley cropping are crop yield increases, fodder, production of staking material, firewood, timber and other various forms of exploitation of the hedgerow species (Kang *et al.*, 1999).

Alley cropping research has been carried out extensively by the International Institute of Tropical Agriculture (IITA), the International Livestock Research Institute (ILRI) and the International Centre for Research in Agroforestry (ICRAF) in Africa since the mid 1970s (Kang *et al.*, 1999). Much hard data has been collected about the tree-crop interface, plant

[1] Alley cropping is also known as alley farming, avenue cropping and hedgerow intercropping (Kang *et al.*, 1999). A similar technology can be used on sloping lands by planting hedgerows parallel to the contours and with an inter row spacing determined by the slope. In this case its purpose is to reduce soil erosion and it may include grass strips as well as trees, some of which may not be pruned. It is therefore functionally different from alley cropping and is known as contour hedgerows (Sanchez, 1995).

litter quality, biological nitrogen fixation, pruning regrowth and adaptation of trees to adverse soil conditions (Sanchez, 1995). A large proportion of the research in Africa has been carried out on-station. On-farm testing of the technology started later but by the 1980s the technology was being promoted by many government and NGO agencies in Africa (Carter, 1995).

However despite the enthusiasm with which alley cropping research was embraced and farmers' interest in the technology the rate of adoption has been well below expectations (Atta-Krah, 1995; Nelson *et al.*, 1998; Kanmegne and Degrande, 2000). Economic assessments calculated from on station trials and secondary sources have been positive. Alley cropping has been shown to decrease fertiliser requirements of maize and to arrest the decline of organic matter over successive seasons. However in on-farm trials researchers have found that complex environmental and social factors influence the effectiveness of the technology and its adoption (Dvořák, 1996).

Table 2.4 summarises the main factors from various adoption studies which limit the feasibility, profitability and acceptability of alley cropping.

Table 2.4 The main limitations to the adoption potential of alley cropping

Type of limitation	Limitation
Feasibility	An inflexible management routine is difficult for farmers to adopt and the penalties are high where management is neglected.
	Hedgerow establishment exacerbates peak labour requirements and maintenance is required during busy periods.
	Hedgerow pruning is viewed as a male task in some areas e.g. Kenya
Profitability	Problems with the biophysical aspects of alley cropping research have led to lower performance on-farm than on research stations. Crop yields are not improved.
	The cost of hedgerow establishment is high.
Acceptability	Investment costs are initially high, but farmers must wait a long time for benefits to accrue.
	Farmers have not perceived soil fertility as a major constraint in some areas used for on-farm trials.
	In areas of high population pressure farmers may not be able to put land under hedgerows, and the opportunity cost of labour may be high. Where population pressure is lower, soil fertility may not be perceived as a problem.

Serious problems with the biophysical aspects of alley cropping research have come to light (Sanchez, 1995). One of these is with the design of alley cropping trials. Trial plots were in many cases so small that tree roots impinged on neighbouring sole-crop treatments invalidating results. Sanchez (1995) considered the balance of competitive and complementary effects under different climatic conditions of valid trials. Where trial plots were large enough under semi-arid conditions competition for water exhibited a stronger influence on crop growth than any complementary effects. Results of on-farm participatory

trials in a semi-arid area of Kenya suggested that soil fertility was not an urgent concern in this environment (David, 1995). Under sub-humid conditions intermediate effects between competition and complementarity provided no positive benefits for crop growth (Sanchez, 1995). In the humid tropics where moisture is not expected to be limiting but soil fertility may be, competition for light or nutrients still exceeded complementary effects. One exception was found on an acid Ultisol in Indonesia using a non-leguminous tree species *Peltophorum dasyrachis* where dense low hedgerows produced a strong mulch/shade ratio with little competition (Sanchez, 1995). Under high rainfall conditions acid soils limit the potential for using nitrogen fixing tree species such as *Leucaena leucocephala* and *Gliricidia sepium* (Whittome *et al.*, 1995). Furthermore, the site suitability of these two tree species, which were almost exclusively focused on in early research, was also sometimes problematic because of their low drought resistance, the limited availability of high quality seed, their susceptibility to pests and their propensity to become weeds (Carter, 1995).

As a result of experimental design problems reducing the profitability of the technology, the performance of alley cropping on farmers' fields was often poorer than on research stations. Dvořák (1996) assessed the potential of alley cropping in the humid and sub-humid tropics and found the constraints were primarily agronomic. Yield gains did not cover the cost of labour for pruning as the biomass yields from hedgerows were much lower on farm than on station. The cost of establishment of hedgerows was also high. Socio-economic analysis of on-farm trials by Swinkels and Franzel (1997) found that mean break even yield increases for maize were relatively low, and lower for returns to land (10.5%) than to labour (17.5%). However, there was little or no yield advantage to the technology. Production of fuelwood and fodder from hedges may offer potential benefits in some areas over and above crop yield and soil fertility benefits (Swinkels and Franzel, 1997; Adesina *et al.*, 2000) but the use of biomass for other purposes will of course, detract from its use in nutrient cycling.

Low profitability is combined with low feasibility of the technology, primarily because of labour constraints. The management regime for hedgerows is inflexible, making it difficult for farmers to adopt, and has high penalties if management is neglected (Dvořák, 1996). Hedgerow establishment exacerbates peak labour requirements, pruning of hedgerows takes place during busy periods, has to be done on a timely basis and is perceived as a male task.

There are also limitations to the acceptability of the technology. There is a long gestation between tree establishment and accrual of benefits (Atta-Krah 1995; Carter, 1995). Some studies have shown that targeting of the technology has been poor with the majority of on-farm trials held in villages where soil fertility is not a major concern of farmers (David, 1995;

Degrande and Duguma, 2000). As previously noted hedgerow establishment and pruning coincides with other farm activities. Adesina *et al.* (2000) found that farmers in areas with high pressure on land were less likely to adopt the technology. This may be because of high opportunity costs of labour associated with other economic activity or alternatively because farmers perceive tree planting as competing with crop production, especially where farmers have adapted the technology to include a fallow phase. This challenges some former views about the suitability of the technology for areas under high population pressure. Adoption potential appears to be higher for men than women, possibly because of bias within extension services towards men or their generally greater wealth (Adesina *et al.*2000).

Where adoption studies have measured longer term use of hedgerows, farmers' adaptations illustrate well the technology design and socio-economic constraints that limit more widespread adoption. Adaptations have been made that reduce the cost of establishment and maintenance in terms of both labour and materials, increase the flexibility of the management regime and provide benefits to the farmer in addition to soil fertility or conservation (Table 2.5). Some adaptations have been made that reduce the cost of the soil fertility element of the technology by omitting the nitrogen fixing component which detracts from the original concept of the technology as providing a low cost sustainable alternative to shifting cultivation, although deep rooted trees may still be able to capture nutrients leached out of the crop's rooting zone (Rowe *et al.* 2001).

Table 2.5 Farmers' adaptations to alley cropping and contour hedgerows

Location and reference	Adaptation	Effect of adaptations
Nigeria, Cameroon and Benin (Adesina *et al.*, 1999)	Introduction of a fallow phase Adjustment to frequency, timing and height of pruning Alteration of spacing between alleys (a few farmers)	Increase flexibility of management regime Decrease labour requirements for maintenance
Humid forest zone of Cameroon (Kanmegne and Degrande, 2000)	Reduction in height and frequency of pruning Introduction of a fallow phase and increase in diversification of cropping pattern Burning of larger quantities of residues Changes to agroforestry tree species used	Decrease in labour requirements Increase in flexibility of management and cropping pattern Increased returns from tree and crop products Changes in soil fertility management Shift from alley cropping to rotational tree fallows

Given the numerous and serious adoption constraints, a number of authors have concluded that alley cropping has a limited recommendation domain, and/or low adoption potential. Sanchez (1995) concludes that 'alley farming will only work in limited and very site specific

circumstances' and where predictive understanding suggests that alley cropping should work, i.e. on fertile soils with a reliable and adequate rainy season other technology options may be more attractive than alley cropping (Sanchez, 1995). Focusing on Africa, Dvořák (1996) concludes that high potential systems for alley cropping cannot be identified on the basis of research to date.

A number of authors have suggested that more specific targeting of alley cropping would be appropriate and have suggested suitable domains for various forms of alley cropping. Dvořák (1996) suggests that where other benefits do not occur (such as production of browse for livestock) a domain where crop productivity gains might induce adoption is where sole maize is grown (cassava/maize, cassava based and second season pulse cropping systems have low potential for the technology) and maize yields are below 2 t ha^{-1} but still able to respond to nitrogen application.

Kang *et al.* (1999) suggest that alley cropping may be suitable in mixed crop livestock systems in the sub-humid zone where tree foliage is used as animal feed but overall, crops are more important than livestock. Where livestock are more important fodder banks may be more attractive interventions for farmers.

Degrande and Duguma (2000) suggest that rotational hedgerow intercropping (i.e. alley cropping with a fallow phase) is suitable where farmers perceive a need for soil fertility improvement and for various tree products, weed invasion is perceived as a problem and a fallow phase can effectively suppress weeds.

In addition to the suggested recommendation domains, there are some basic requirements common to all variants of alley cropping in all ecological areas. The availability of sufficient labour and a degree of flexibility is one of the foremost requirements. The opportunity cost of labour should be low i.e. there should be a lack of on and off-farm opportunities (Dvořák, 1996; Degrande and Duguma, 2000). Land should be a greater constraint than labour (Kang *et al.*, 1999), with shortening fallows and declining soil fertility (Whittome *et al.*, 1995). However where pressure on land is too excessive farmers may be unwilling to use land for alley cropping (Adesina *et al.*, 2000). Whittome *et al.* (1995) suggests that population density should exceed 30 people km^{-1} and provides a recommendation domain for West African regions (Figure 2.1) where rainfall exceeds 1 200 mm but soils are not acidic. Long term security of land tenure and the ability to plant and maintain trees is also necessary (Whittome *et al.*, 1995; Degrande and Duguma, 2000).

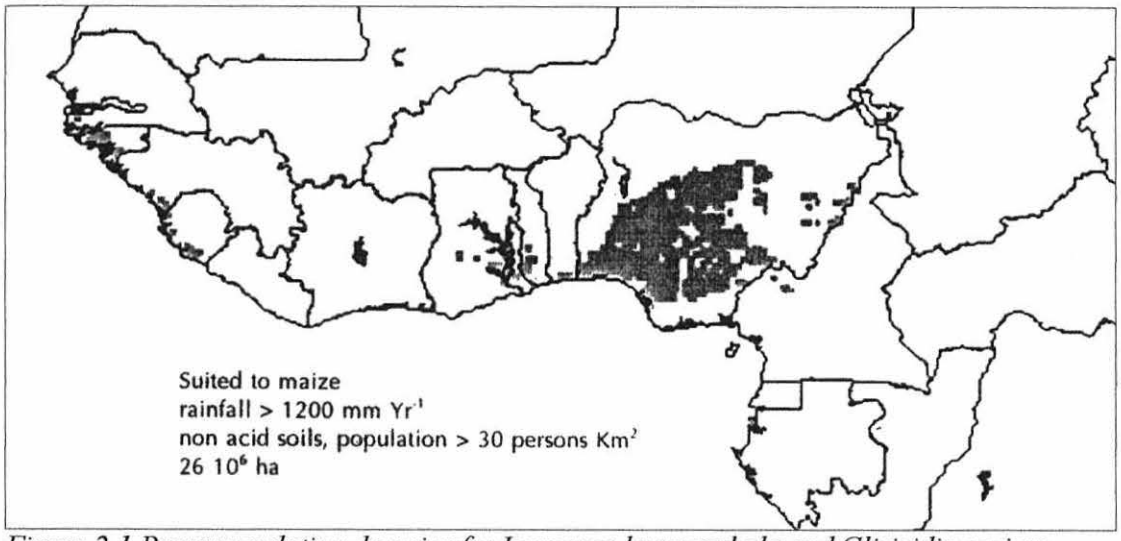

Figure 2.1 Recommendation domains for Leucaena leucocephala and Gliricidia sepium based alley cropping for West African regions. Shaded areas (excluding water bodies) have annual rainfall > 1 200 mm, non-acid soils and population densities > 30 persons km^{-2}. Source: Whittome et al. (1995)

Overall the various forms of alley cropping have limited appeal for farmers. The labour intensive nature of the technology, competing on-farm labour demands, limited profitability, and delayed returns on investment make it unattractive. Finding areas that correspond to the recommendation domains mentioned above where farmers perceive benefits from alley cropping and do not have alternative uses for land and labour would require very specific targeting.

2.2.2 Cover crop technologies in Latin America and West Africa

The adoption of cover crops by smallholder farmers has generally been heralded as more of a success than alley cropping. In Central and South America in particular, integration of cover crops into farming systems is advanced and can provide historical lessons concerning farmer adoption of complex technologies.

Cover crops are also referred to as live mulch, organic mulch, green manure and slash/mulch systems. Anderson *et al.* (2001) gather a number of different definitions of the concept but for the purposes of this discussion cover crops are defined as 'temporary or permanent, live, non-woody, vegetative soil cover grown within rain-fed annual or perennial cropping systems to improve the soil through creating a favourable micro-climate, decreasing evaporation and protecting the soil from erosion whilst producing biomass that can be used as forage or add organic matter to the soil.' (adapted from Kiff *et al.*, 1996 and Bayer and Waters-Bayer, 1998).

Anderson *et al.* (2001) brings together a number of case studies of traditional or recently introduced but relatively successful legume integration in Latin America (Table 2.6). Each case involves the incorporation of a leguminous crop into farming practices. What is noticeable in the traditional use of cover crops is that the cover crop provides either human food or fodder, and it has been integrated into the farming system in such a way as to require minimal additional labour inputs. Hence, although there are benefits in terms of soil fertility and weed suppression there are also other material advantages. In both cases where mucuna has been introduced as a cover crop, yields are increased and forage is produced although labour inputs have also increased.

Table 2.6 Cover crop use in annual cropping systems in Latin America from Anderson et al., 2001

Location	Biophysical conditions	Cover crop	Cropping pattern	Benefits of cover crop use	Level of success/adoption
Lowland southern Honduras	Poorly distributed rainfall between 1 400 mm and 1 600 mm per year. Stony soils low in organic matter.	*Vigna spp.* mostly cowpea (Vigna unguiculata).	Mixed cropping of maize, millet and various *Vigna* species which mature 40 days to 4 months after planting. All three crops are planted together in the same hole.	- Human food (*Vigna* is reliable and drought tolerant compared to other crops in the region and early maturing types provide food in a period of scarcity). - Forage. - Weed control and soil fertility improvement.	Traditional cover crop use.
Hillside area of Honduras	1 500 to 2 000 mm rainfall per year. Deep volcanic soils with moderate levels of organic matter on slopes of 15 – 70% susceptible to erosion. Altitudes between 1 400m and 2 000m.	*Phaseolus vulgaris* and *P. coccineus.*	Mixed cropping of maize and beans. Beans are sown together with the maize and also resprout from tubers in the soil	- Human food and crop diversification - Forage. - Weed control and soil fertility improvement.	Traditional cover crop use.
Highlands of Bolivia	800 to 900 mm rainfall per year. Altitudes between 2 800 and 3 400 m.	*Medicago hispida* (*garotilla*) – a local legume.	Wheat, oats, maize, barley, potatoes and other crops with *garotilla*. The seed is distributed through animal droppings.	- High quality forage which can be stored and fed in times of scarcity. - Weed control and soil fertility improvement.	Traditional cover crop use.
Yucutan, SE Mexico	800 to 1 400 mm rainfall per year.	*Mucuna pruriens* (mucuna).	New maize varieties sown in furrows on accumulated organic material intercropped with mucuna.	- Increased maize yields. - Earlier harvesting of maize which can then be sold. - Forage.	Participating farmers have increased the area to this cropping pattern and none have abandoned it in four years of study.
Guimaca, Honduras		Mucuna.	Intercropping of mucuna with maize and beans in a zero tillage system.	- Increased maize and bean yield. - Earlier harvesting of maize which can then be sold. - Forage.	Introduction of mucuna more successful than live barriers in 25 communities where it was introduced.

The widespread use of mucuna (*Mucuna pruriens*) in conjunction with maize cultivation, a practice known as *abonera*[2], in the hills of northern Honduras has commanded a lot of attention and has been studied in depth. Mucuna seed was introduced in the early 1970s and spread slowly for the first ten years after which use spontaneously exploded in the region so that by the early 1990s almost two-thirds of farmers were using mucuna to grow second season maize (Buckles *et al.*, 1998b).

Whether this result can be replicated elsewhere, on the same scale, remains to be seen. A number of factors listed below, which may be directly or indirectly location specific to northern Honduras, may have contributed to the popularity of the technology (Buckles *et al.*, 1998b; Buckles and Triomphe, 1999):

- Annual rainfall exceeds 3 000 mm. There are two wet seasons and the growing period is in excess of 270 days; the second season is better for maize production than the first.
- The growing season for the mucuna crop is seven to eight months enabling sufficient and reliable biomass accumulation of 10 to 12.5 t ha^{-1} dry matter.
- Mucuna self seeds once it has been established thus minimising further additional labour inputs for the maintenance of the cover crop.
- The cover crop aids weed suppression.
- Soils are relatively deep and fertile and land is steeply sloping in hilly areas.
- Traditional agriculture is based on slash and burn cultivation with fallows of four to ten years. The *abonera* system enables farmers to cultivate the same field year after year with no decline in yield.
- Maize cultivated in the *abonera* system enjoys yield advantages of 50 to 100% over growing maize with a natural fallow.
- Market prices are favourable for second season maize due to different climatic conditions in the rest of the country which prevent the growth of a maize crop in this season, and maize import restrictions.

Maize cultivation in the *abonera* system works. It works biophysically by rapidly recycling soil nutrients, providing some weed suppression and most importantly raising yields over a natural fallow. It also works socio-economically because labour costs are minimal for sustaining the improved fallow system, and because market prices for second season maize are favourable.

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[2] In the *abonera* system mucuna is relay cropped with second season maize and accumulates biomass during the main wet season. One maize crop is grown annually and after establishment farmers rely on
Footnote continued on next page

Farmers' decisions to adopt mucuna appear to be closely related both to livelihood strategies and resource endowments (Buckles *et al.*, 1998b). Four key factors influence farmers' adoption of the technology: security of tenure, the opportunity cost of land, land characteristics and the market orientation of maize producers. These factors are related to livelihood strategies and resource endowments, particularly land (
Table 2.7).

Table 2.7 Factors influencing adoption of the abonera system

Farmer characteristic influencing adoption	**Influence on adoption**	**Explanation**
Livelihood strategy		
Sale of second season maize	+	There are better market prices for second season maize compared to first season maize.
Attempts to diversify into cattle ranching	-	Farmers attempting to diversify into cattle ranching may not have sufficiently large land holdings and experience a higher opportunity cost of land and other resources.
Resource endowments		
Steeply sloping maize field	+	Potential benefits of using mucuna are greater on this land type.
Secure tenure	+	Small-scale farmers are able to rent land for first season food crops whilst using their own land for the *abonera* system.

More recently there have been reports that the use of mucuna in northern Honduras has been declining with a rate of abandonment exceeding 10% per annum by 1997 (Neill and Lee, 2001). Examination of this decline confirmed the socio-economic factors which influence the initial adoption of this cover crop system. It also confirmed external, biophysical and farm management factors which have led to changes in the opportunity costs of land and labour. The size of land holdings has decreased and the land rental market has contracted as a result of the increase in cattle ranching and a land titling program. A new road has improved infrastructural access, there have been unusual weather patterns and a noxious weed (*Rottboellia exaltata*) has disrupted the minimum labour required to maintain an *abonera* fallow. Overall, more commercially orientated farmers are more likely to continue using the *abonera* system, providing more effective management of the mucuna fallow through reseeding than farmers whose interests are more in off-farm employment and who do not reseed fallows and are more likely to apply herbicides to combat weeds.

These case studies illustrate the requirements which may be necessary for cover crop technologies to be adopted into farming systems. The disadoption of mucuna illustrates the fine balance to the opportunity costs of land and labour and shows how broader socio-

the mucuna self seeding each year for continuation of the system (Buckles *et al.*, 1998).

economic and policy factors make sustainable agricultural technologies attractive. A mucuna then maize rotation worked in the relatively well-endowed biophysical environment of northern Honduras. However, not all regions have such favourable climatic characteristics, although there are many different species of cover crop which have potential for incorporation within farming practices and each crop has its own complex of biophysical requirements and potential products (Table 2.8).

Table 2.8 Characteristics of cover crops which influence their suitability for integration into cropping systems

Biophysical Requirements	Growth Characteristics	Potential Products
Temperature	Morphology (tree, shrub etc.)	Human food (grain or leaf)
Rainfall	Growth type (e.g. erect,	Animal fodder (green or dry)
Altitude	spreading, climbing)	Nitrogen fixation
Soil pH	Life cycle duration	Protection from erosion
Drought tolerance	Initial growth rate	Weed suppression
Soil fertility	Productive growth rate	Pest deterrent
Soil texture		
Tolerance to water logging		
Susceptibility to pests		

Source: University of Wales, Bangor, 2003b

A cover crop must match a set of biophysical requirements to be suited to an agro-ecological niche within a particular farming system. Furthermore, for adoption to take place, the cover crop's benefits must be considered worthwhile after consideration of the opportunity cost of land and labour necessary for its cultivation under local socio-economic conditions. Cover crop seed must also be available for diffusion amongst farmers to take place. Availability of seed is often mentioned as an issue (e.g. Carsky *et al.*, 2000; Anderson *et al.*, 2001) and is particularly relevant when there are many different species and varieties to experiment with and before a practice has become widespread. Overall, research on the adoption and use of cover crops from Latin America reported in the literature confirm Bunch and Buckles (1998) statement that small-scale farmers will only accept cover crops when:

- they are grown on land that has few opportunity costs,
- their use requires little additional labour,
- seed is readily available at no out-of-pocket cost to the farmer, and
- their biomass provides benefits over and above improvements to soil fertility, usually in the form of human food or livestock fodder.

Experiences with cover crops in West Africa have been more recent than in Latin America. The adoption of mucuna in Benin has been the most successful case so far. Mucuna seed was distributed in an intensive campaign by Sasakawa Global 2000 and 10 000 farmers were estimated to be testing the technology in 1996 (Galiba *et al.*, 1998). Mucuna, either sole

cropped or intercropped with maize, has been found to suppress *Imperata cylindrica* which is a problem weed in the area and this has been found to be the most important factor in farmers' adoption decisions. Land tenure security, type of soil, farmers' age and farmer contact with extension services, market opportunity for mucuna grain were also found to be determinants of adoption (Manyong *et al.*, 1999). Loss of a second season crop was the most important constraint to adoption, and other constraints included land scarcity, lack of secure land tenure, lack of availability of seed, lack of information, bush burning, the limited range of associated crops, and toxicity of mucuna seed for human and livestock consumption. These findings are consistent with Bunch and Buckles (1998) observations about adoption of cover crops mentioned above.

Differences between farming systems and practices in Latin America and West Africa should be considered in research and extension activities and may lead to different experiences with cover crop technologies. The integration of crops and livestock in West Africa is much less advanced than in Latin America. There is, therefore, either less opportunity or more obstacles, for the use of cover crop biomass as livestock feed. Although the case studies presented by Anderson *et al.* (2001) (Table 2.6) confirm that cover crops have been adopted into farming systems in areas with poor natural resource endowments the opportunity costs of land are likely to be higher than in areas with better rainfall and soils. Sloping lands may also favour the adoption of cover crops where farmers perceive soil erosion to be a problem that has consequences for farm productivity. Finally, mixed cropping systems are common in West Africa and the opportunity cost of land is increased where cover crops are only suitable for monocropping patterns.

Promotion of cover crops should be approached with care as external and local objectives for the use of cover crop technologies seldom coincide (Table 2.9) (Anderson *et al.*, 2001). In Benin, mucuna was tested for its soil fertility benefits and it was farmers who first noted its ability to suppress *Imperata cylindrica*. Successful adoption of cover crops and other resource conserving technologies requires that the technology has perceived benefits for all stakeholders. Successful incorporation of a cover crop into a local farming system requires that it is locally adapted and can be closely integrated with farming practices. It must provide acceptable benefits to farmers to justify the opportunity costs of land and labour. Experimentation by farmers is, therefore, most likely to produce adoptable technologies.

Table 2.9 Land use priorities for primary and secondary stakeholders (Anderson et al., 2001)

Stakeholder	Land use purpose			
	Resource conservation	**Soil and water conservation**	**Income generation**	**Subsistence production**
Farmer	Low priority	Low priority	High priority	High priority
Government organisation	Medium priority	High priority	Medium priority	Medium priority
Donor	High priority	High priority	Low priority	Medium priority

2.3 Soil fertility technology development and adoption in Ghana

The literature reveals little evidence of continued, significant adoption of soil fertility research outputs that have been developed or evaluated by research and/or promoted by extension in the forest and transition zones of Ghana (Table 2.10). However, improving soil fertility management is recognised as a key issue for agricultural development and the Government of Ghana has produced a soil fertility management action plan (MOFA, 1998). Other assessments of soil fertility and the adoption of soil fertility technologies in Ghana have been carried out by Amanor, (1996); Bonsu *et al.*, (1996); Harris, (1997); Harris *et al.*, (1998); Fawcett and Smith, (1999); Quansah (1999); Kranjac-Berisavljevic' *et al.*, (2000); and ODI, (2000). Some participatory on-farm research has been initiated in the last three or four years but results have yet to be extended to farmers over a wide area (e.g. Kiff *et al.*, 1997; Zschekel *et al.*, 1997; Quansah, 1999).

Traditionally, farmers have used fallowing to restore soil fertility. The use of inorganic inputs has been promoted by the extension services, however the use of organic soil management technologies has received less attention. Much research has been carried out using inorganic fertiliser, and recommended application rates exist for the majority of crops. Fertiliser was used more extensively when subsidized prior to 1992. Currently use by small-holders in the forest and transition zones is restricted to commercial farming enterprises, predominantly vegetable farming, but also for rice where it is considered necessary, and occasionally for maize and for oil palm nurseries.

Research has been carried out on mulch and 'no burn' farming, and this has been promoted, particularly following the bush fires of 1983 but has proved an unpopular option. Animal manure, compost, and cover crops have been promoted less extensively, and are little used, except to a limited extent in peri-urban Kumasi where some commercial vegetable producers use poultry manure from large poultry farms in the area. Cover crop seeds and manure are not widely available elsewhere.

Table 2.10 Adoption of soil fertility research outputs in the forest - agriculture interface in Ghana.

Type of Technology	Details of technology	On-farm testing/farmer participation in technology design and method of dissemination	Farmer adoption	Proposed reasons for adoption/lack of adoption
Inorganic fertilisers	Recommendations for new varieties of maize, fertiliser use and optimal planting practices (line planting/optimal plant population density) for monocropped maize (Tripp, 1993).	On-farm adaptive trials involving collaboration between the Crop Research Institute, the Grains and Legumes Development Board (GLDB) and the Ministry of Food and Agriculture (MOFA). Centrally organized, hierarchical research using farmer feedback but without active farmer participation. Extensive extension programme in conjunction with trials (following a number of previous inorganic fertiliser awareness raising campaigns).	Significant adoption rates for the package in the 1980s. However, fertiliser use in general fell in the 1990s. Commercial vegetable production is heavily dependant on inorganic fertilisers, use on cereals is more common in the savanna than the forest zones. In the forest zone perennial and root crops do not usually receive fertiliser (Kiff and Floyd, 1997; Harris *et al.*, 1998)	A number of campaigns have promoted fertiliser use in Ghana, but significant adoption only came with a focused program of on-farm research and an extension strategy that brought recommendations to farmers in terms they could understand. Since 1990 low levels of use reflect policy changes (lifting of subsidies and privatization of the input market) which have increased the cost and lowered the economic returns to usage. Considering the number and scale of projects to raise awareness about inorganic fertilisers it is unlikely that there are many farmers unaware of their use.
Inorganic fertilisers for mature cocoa production	Research has shown mean cocoa yield increases of 62 – 116% of fertilised mature cocoa plots over unfertilised plots, although response varied depending on site and management. Fertilised yields were over twice the national average. Fertiliser use was calculated to be economically feasible with a cost benefit ratio over 3.00, although the means of valuation are not given (Appiah *et al.*, 1997).	On-farm research (managed and supervised by field assistants). The Cocoa Services Division has recommended inorganic fertiliser use to farmers (Manu and Tetteh, 1987).	No evidence	Farming has traditionally relied on extending land area to increase productivity. Although some evidence of different strategies for management have suggested that care-taker farmers are more interested in intensifying production than owner farmers (Blowfield, 1995), other evidence suggests more efficient labour inputs to cocoa yields are obtained by caretakers using less labour.
Oil palm and cocoa husk residues	Research outputs have shown that oil palm and cocoa husk residues both have a high K content and oil palm has a high pH with the potential for ameliorating soil acidity (Bonsu *et al.*, 1996; Owusu-Bennoah, 1997)	On-station trials No evidence of dissemination. More interest in industrial development.	Oil palm husk may be recycled by oil palm growers.	
Continuous cultivation using cover crops and mulches	Research by IITA in Nigeria has shown that planting through a live or dead mulch (involving herbicide use) of an established cover crop (*Centrosema pubescens* or *Psophocarpus palustris*) can sustain maize yields at 2.1 – 2.2 t ha^{-1}. Research in Ghana has shown that land preparation without burning cleared bush can increase maize yields over normal land preparation with the use of inorganic fertilisers (Mulongoy and Adobundu, 1992 and Ghana Grains Development Project, 1992 in Bonsu *et al.*, 1996). Continuous cultivation with/without herbicides, and with/without cover crops and/or chemical fertilisers in the forest zone has also been tested (Fedden, 1986).	Some on-farm trials using herbicide and/or mulches have taken place in Ghana. It is unclear to what extent these technologies have been disseminated as the extension services have concentrated messages on the use of inorganic fertiliser.	Some evidence of *proka* (land preparation without burning) was found by Amanor (1996) in areas dominated by *Chromolaena odorata*. No suggestions are given as to why this is the case.	Farmers have reported that planting through cut bush leads to high rates of weed infestation and low yields and labour is one of the main constraints in farming systems. However herbicides are likely to be beyond the means of many food crop farmers.

Table 2.10 continued

Type of Technology	Details of technology	On-farm testing/farmer participation in technology design and method of dissemination	Farmer adoption	Proposed reasons for adoption/lack of adoption
Green manures, cover crops and other leguminous annuals in rotations.	Some research has taken place obtaining higher maize yields with *Mucuna pruriens* in the forest zone (Boateng, 1997). The Integrated Food Crop Systems Project (IFCSP) has been experimenting with *Mucuna*, *Canavalia* and *Crotalaria* on vegetable production in the transition zone (Jackson *et al.*, 1999).	On-farm trials have been undertaken by the IFCSP with a range of farmers with different resource endowments with inputs provided by the project.	On going project. A 3-year crop rotation with maize, cowpea and cassava is replacing long duration intercropping in the transition zone. It is also displacing minor season maize in some areas of the forest zone. Cowpea cultivation has been the most successful innovation in the transition area (Amanor, 1993).	Cowpea is a good cash earner but requires pesticides. Yields are more stable than maize under lower rainfall but in more forested *Chromolaena odorata* dominated areas yields are lower and systematic integration of cowpea into the crop rotation is absent. The main incentive for adoption is favourable market price. The main problems with adoption have been poor rainfall, low rates of regeneration on grassland and the long period required to clear grassland for cultivation (Amanor, 1993).
Animal manures	The Land and Water Management Project and the IFCSP have undertaken on-farm trials (Jackson *et al.*, 1999). Poultry manure at 4 t ha^{-1} has been found to increase maize grain yield by 53 - 67%, and cassava by 76 - 83% over a control over a 3 year period year in an intercropping trial (Quansah *et al.*, 1998a in Quansah, 1999). Integrated (organic and inorganic) nutrient management trials have also been carried out with positive results.	On-farm participatory trials. Inputs were provided by IFCSP.	In some areas where it is available there is some evidence of the use of poultry manure, but much remains unused (Brooke and Dávila, 2000; Drechsel *et al.*, 2000).	Low level of availability of manures and perceptions that using animal manure is dirty and old-fashioned rather than a modern practice have been suggested as reasons for low levels of use of animal manures (Harris *et al.*, 1998). The success of poultry manure trials has been attributed to farmer participation in the technology development and the support of local leadership.
Cover crops grazed by sheep under cocoa	Kade Agricultural Research Station, (University of Ghana, Legon) (Fianu, 1998) has tested a number of different cover crops with sheep integrated into the system.	Researcher managed trials No evidence of dissemination.	No evidence of adoption	Adoption of this practice would require a large initial investment, and good access to markets for the purchase and sale of sheep, whereas infrastructural development generally decreases further south in the forest zone, (except for the provision of services relating to cocoa).
Alley cropping	Positive outputs from on-station trials using leguminous trees such as *Leuncaena leucocephala* and *Gliricidia sepium* are reported by Fedden (1986)	Adaptive trials throughout the country. Demonstration plots were set up by MOFA throughout the country (Anane, 1994 in Lawson, 1995). Introduced to the Mampong valley of the Eastern region by an NGO in 1988 (Lado, 1998).	Failed adoption in the Mampong valley (Lado, 1998). No evidence of adoption elsewhere.	Excessive labour requirements, weediness of some leguminous trees and crop competition have been suggested (Anane, 1994 in Lawson 1995; Bonsu *et al.*, 1996). Lado (1998) suggests that tenure was an additional constraint to some farmers.

The use of inorganic fertilisers

All inorganic fertilisers used in the country are currently imported into Ghana, although there has been some research into the potential of using local sources of phosphorous and potassium. Owusu-Bennoah (1997) reviews Ghana's indigenous fertiliser resources. Tetteh and Quayson (1997) report that urea is now the main nitrogen fertiliser used by farmers in Ghana.

There is heavier dependence on chemical fertilisers for growing food staples in the savanna zone than in the forest zone. In the south of Ghana the use of inorganic fertilisers is significantly higher in peri-urban than in rural areas reflecting the greater intensity of commercial vegetable production closer to market centres (Harris *et al.*, 1998). Commercial vegetable production in the Brong Ahafo region is highly dependant on chemical inputs for providing plant nutrients (Kiff and Floyd, 1997). Cocoa farming has traditionally taken place without the use of chemical fertilisers with productivity increases taking place through expansion of farming rather than more intensive farming (Appiah *et al.*, 1997).

Serious experiments with fertilisers started in the 1940s, initially on agricultural research stations. Systematic fertiliser trials were started in all agro-ecological zones in the 1960s under the FAO Freedom From Hunger Campaign and adaptive trials have been components of a number of other projects since. Projects that have raised awareness about mineral fertilisers have included "Fertiliser Pilot Scheme" (mid 1960s), "Operation Feed Yourself" (late 1960s), FAO Freedom from Hunger Campaign, UNDP/FAO assisted "Increased Farm production through Fertiliser Use", USAID sponsored "Focus and Concentrate Programme" (1970s), a GTZ assisted fertiliser project in the Northern Region, the Ghana Grains Development Project maize research programme, the Sasakawa Global 2000 Project (late 1980s) and the Training and Visit extension programme. It is unlikely that there are many farmers unaware of their use (Tripp, 1993; Acquaye, 1997).

The rate of consumption of different fertilisers increased from the 1960s to the 1980s, and then declined during the 1990s from 65 239 Mt in 1989 to 11 600 Mt in 1994 (Bonsu *et al.*, 1996), and from 4.5 to 2.9 kg ha^{-1} from 1994 to 1996 (Quansah, 1999). This is mainly thought to be because of the steep rise in the price of fertilisers and is associated with structural adjustment. Additional problems that have been identified are the appropriateness of fertiliser recommendations, farmer cash flow problems and problems associated with distribution and these have been documented by Bonsu *et al.* (1996), MOFA (1998) and Quansah (1999).

The steep increase in the price of inorganic fertilisers follows the persistent devaluation of the cedi and the withdrawal of subsidies. Until 1987 farmers enjoyed a 45% subsidy on the cost of fertilisers. Subsidies started to be withdrawn in 1988 and were completely withdrawn by 1992. The Value Cost Ratio (VCR) for fertiliser use calculated for maize for the period 1989 to 1994 showed that the VCR fell in this period and was below 2 in the period 1992 to 1994, the level below which fertiliser is not considered economically advantageous (Bonsu *et al.*, 1996).

Prior to 1990 MOFA was responsible for the procurement, distribution and sales of fertiliser. In 1990 and as part of the Economic Recovery Programme, the fertiliser sector was privatised and fertilisers were imported by private importers with the prior approval of MOFA and the Environmental Protection Agency (EPA). However, privatisation is not considered to have improved procurement and distribution. The past government monopoly on imports has been replaced by a private sector monopoly, a development that has been partially attributed to the limitations imposed on obtaining credit because of high interest rates and bank charges, that make it difficult for entrepreneurs to finance importation. Additional problems associated with marketing are inaccessibility, price instability and inadequate storage facilitates. The inadequacy of the fertiliser distribution network has been attributed to the small size of the market for fertiliser in relation to the investment required from importers, distributors, wholesalers and retailers which compares unfavourably with other investment opportunities. It is also suggested that those in the fertiliser trade lack the skills to make their trade efficient and cost effective in terms of planning fertiliser supply, fertiliser needs, knowledge of the international markets and the importance of dealer networks, and additionally that private sector operators, and those involved in marketing fertiliser, may not have the knowledge of the efficiency and effectiveness of fertilisers (MOFA, 1998).

Lack of sources of agricultural credit to farmers is also considered to be a constraint to the use of inorganic fertiliser. Following the Financial Sector Reform Programme (FSRP) in the 1980s lending to the agricultural sector declined from about 30% of loanable funds of banks to less than 10% in 1998. This was partially due to the relaxation of the Bank of Ghana's supervision of credit guidelines which enabled banks to move to more profitable schemes in the commercial sector which paid a higher interest rate and were considered less risky. Some rural bank branches were also closed. Additionally it has been suggested that existing tenure arrangements may limit farmers' ability to use land as collateral for loans (MOFA, 1998).

MOFA (1998), states that recommendations for fertiliser application rates to major food crops are out of date, some being formulated over 25 years ago, and that advice on timing and

methods of application to increase fertiliser use efficiency are also necessary. However, given the number of fertiliser programmes and projects that have taken place including Sasakawa Global 2000's adaptive maize trials (Tripp, 1993), this may only be partially true. Soil testing services are available in Ghana, and can provide guides to NPK application rates and liming recommendations for acid soils, but their use is less frequent since the introduction of high yielding varieties, the removal of fertiliser subsidies and the consequent low level of fertiliser usage (Acquaye, 1997).

It is unclear to what extent the factors outlined above have changed inorganic fertiliser usage by smallholders. It has been suggested that the increase in fertiliser prices may have largely affected wealthy, larger scale farmers rather than smaller scale subsistence farmers, as the previously low costs may have encouraged inefficient use of inputs (Seini and Jebuni, 1992 in Owusu-Bennoah, 1997).

The use of leguminous cover crops and green manures

Farmers in Benin have been adopting mucuna (*Mucuna pruriens*) as a cover crop where the main benefit is seen as the suppression of *Imperata cylindrica* (Vissoh *et al.*, 1998) and there are some reports of a few farmers in Ghana also adopting mucuna. Mucuna and canavalia (*Canavalia* spp.) have been minor food crops in Ghana for at least a century. A few plants are grown by women and the beans are regularly consumed in stews and soups. Mucuna is more popular than canavalia, and almost as popular as lima beans (*Phaseolus lunatus*), which are used more frequently by households in the transition zone than elsewhere. However, Osei-Bonsu *et al.* (1996), found farmers unfamiliar with their use as cover crops or green manure, although they were familiar with *Pureraria spp.* and *Centrosema spp.* as cover crops on plantations. Some on-station research in the forest zone has resulted in maize yield increases over natural fallow (Boateng, 1997).

On-station and on-farm trials with a number of green manure species for dry season tomato production were carried out in the Brong Ahafo region and the most successful green manures - *Mucuna pruriens*, *Canavalia ensiformis* and *Crotalaria* spp. were identified as suitable for promotion (Jackson *et al.*, 1999). The potential of green manures for wet season tomato was also assessed considering the necessary adjustments to labour requirements and input costs and other constraints to production (Dorward *et al.*, 2003). This assessment concluded that green manures would only be viable where soil fertility was a major constraint – a factor related to population density. In other areas various marketing problems needed to be addressed before increasing yields would be profitable, and adoption would only produce significant benefits to farmers who were highly commercially orientated and for whom

marketing was not a problem. Amanor (1993) reports that cowpea (*Vigna unguiculata*) has been the most successful innovation in southern Ghana. In the forest area, yields are more stable than minor season maize under lower rainfall, and it is used in the transition area as part of a three-year rotation with maize and cassava, where the labour required to clear grassy weeds makes more continuous cultivation with crop rotations favourable. Cowpea is also a good cash earner. However, Arokoyo (1998) reports that some improved high yielding varieties of cowpea have had limited adoption success due to the high cost of pesticides which are essential for production, whereas local varieties, although low yielding, have some pest tolerance.

Planting crops into a live mulch, which involves the establishment of a cover crop (*Centrosema pubescens* and *Psophocarpus palustris*) first (to avoid crop competition), followed by planting crops in narrow strips made in the mulch with a cutlass, has also been recommended to farmers in Ghana. Research by the International Institute of Tropical Agriculture (IITA) in Nigeria has shown this method to be capable of sustaining maize yields at 2.1 – 2.2 t ha^{-1} with no response to nitrogen fertiliser after four years. Alternatively the mulch may be killed off before planting using a contact herbicide or cutting the stems mechanically and leaving them on the field. Research at IITA showed no significant response to N fertiliser with this treatment (Mulongoy and Adobundu, 1992 in Bonsu *et al.*, 1996). Minimum tillage systems and the use of vegetative biomass as mulches have been tested partly to reduce the use of fire for land clearance. Research by the Ghana Grains Development Project found that maize yields were higher where land was not burnt and no chemical fertiliser was applied than where land was burnt and had chemical fertiliser applied (Ghana Grains Development Project, 1992 in Bonsu *et al.*, 1996), but this contrasts with reports of farmers' own findings that planting through cut bush leads to high rates of weed infestation and low yields (Amanor, 1994; 1996). Nye and Greenland (1960) claim that burning is the only way to clear land in the forest zone, and the simplest means to get rid of grassy weeds in the savanna zone, using hand hoes for burying grass being quite impractical. Burning is the most economical way of getting rid of trash, controlling weeds and eliminating snakes, rodents and insects. The ash provides a transient supply of nutrients, particularly K, Mg and Ca. Minimum tillage systems for rotational cultivation have been developed at the Technology Consultancy Centre (TCC), in Kumasi. However, herbicides are expensive and Fedden (1986) suggests that this system is only likely to be used by progressive farmers growing high yielding crops. The package also recommends the use of fertiliser on high yielding crop varieties and a leguminous cover crop such as cowpea, which may also require a fertiliser starter on soils of low fertility.

Agroforestry

An agroforestry system incorporating a mixture of cover crops under cocoa which are grazed by sheep has been tested at Kade Agricultural Research Station, University of Ghana, Legon (Fianu *et al.*, 1996; Fianu, 1998). Although this system might appear attractive it would require a significant change from traditional systems, a large initial investment, and a means of transporting sheep to market.

The Forest Research Institute in Ghana (FORIG) has initiated agroforestry experiments including the integration of *Senna siamea, Eucalyptus tereticornis* and *Leucaena leucocephala* with food crops and improved fallows with *Cassia* sp., *Albizia* sp. and *Casuarina* sp. (Annual Report 1994 in Lawson, 1995). Demonstration plots of a number of agroforestry techniques (alley cropping, woodlots, fruit-trees with arable crops, wind breaks around plantains, in-situ yam staking and fodder banks) were established by the Agroforestry unit of the Ministry of Food and Agriculture (MOFA) in 10 regions and are used for farmer training. Adaptive trials have also taken place in all administrative districts (Anane, 1994 in Lawson, 1995). Alley cropping trials have taken place at the Technology Consultancy Centre (TCC) Minimum Tillage Pilot Project Farm in the forest zone after recognition of the need to find an alternative to the use of herbicides in minimum tillage systems. However, adoption has been very slow and the technology has proved unpopular. Suggested reasons have been the excessive labour required for pruning, the shattering of *Leucaena leucocephala* seeds which germinate causing weed problems, the land tenure systems which do not allow the planting of trees by tenant farmers, crop competition and grazing damage (Anane, 1994 in Lawson (1995); Bonsu *et al.*, 1996). Amanor (1993) also reports that farmers dislike *Senna siamea, Azadirachta indica* and *Leucaena leucocephala* which, since their introduction in fuelwood and agroforestry schemes, have become the dominant trees in some areas suppressing the regeneration of forest species. *S. siamea* is recognised as having a beneficial effect on maize but is considered bad for cassava. Where *Leucaena leucocephala* dominates the fallow land is often not cultivated as *L. leucocephala* is difficult to clear and reproduces rapidly. Prospects for development and use of native trees in agroforestry systems have not received research attention.

Animal manures

Poultry manure around the city of Kumasi is mostly used on vegetable crops, although it has also been found to increase average maize grain yield by 53% and 67%, and cassava by 76% and 83% over a control over a three year period in trials in the forest zone (Quansah *et al.*,

1998a in Quansah, 1999; Brook and Dávila, 2000; Drechsel *et al.*, 2000). Much manure produced by large-scale livestock farming in peri-urban Kumasi remains unused.

Trials of a number of different animal manures have been carried out in the Brong Ahafo region. Some initial resistance amongst farmers to test manures was found as manuring is viewed as an old-fashioned practice, involving 'dirty work' that might attract ridicule from fellow cultivators who would think users too poor to afford chemical fertilisers (Kiff *et al.*, 1997; Jackson *et al.*, 1999). Harris *et al.* (1998) also note that in the forest zone there is considerable social stigma attached to handling manure which may contain human excreta and rubbish, although this is not evident in the savanna zone. Farmers were enthusiastic about the results of the trials but it remains to be seen whether adoption will be sustained and if the use of animal manure will spread. The GTZ (German Development Co-operation) funded Sedentary Farming Systems project is also promoting the use of animal manure and composting in the Brong Ahafo region (Kiff and Floyd, 1997).

2.4 Conclusions

The conditions for agricultural intensification and farmer investment in soil fertility management are time and location specific. A complex set of biophysical, socio-economic and institutional factors influence the opportunity costs of land and labour. Simple hypotheses that farmers will invest in soil management due to population pressure, and declining bush fallow rotations are insufficient. Investment in soil fertility should be viewed within the context of broader livelihood strategies that include both on-farm and off-farm income generating opportunities and markets for agricultural products.

Ruttan and Hayami (1998) have outlined a model for successful agricultural development involving demand driven technologies called the Induced innovation model. There is currently interest by donors and development practitioners in democracy, decentralization and increasing the role of farmers' organizations in sub-Saharan Africa, all elements which could influence the success of this model. Nevertheless, these elements are not yet in place. The institutional context for the generation and dissemination of soil fertility technologies will be examined in Chapter 6.

Alley cropping is an example of an unsuccessful soil fertility technology developed more due to the interests of natural resource researchers than due to demand from farmers. Cover crops have potential in West Africa, but lessons can be learned from Latin America about the conditions under which they are likely to be successful – few opportunity costs of land, little

additional labour, readily available seed and benefits in addition to improvements in soil fertility. There have been strong positive incentives for the widespread adoption of mucuna in Honduras under a spatially and temporally specific set of biophysical and socioeconomic conditions.

In Ghana most emphasis in soil fertility management has been put on the use of inorganic fertilisers, which, since structural adjustment and the associated increase in fertiliser prices, has become uneconomical for farmers to use except on the highest value cash crops. Historically crops and livestock have not been integrated and farmers have relied on bush fallowing. For farmers to adopt more action orientated soil fertility management practices would therefore involve quite a major conceptual change. Strong incentives to do so are not in place. Increased farmers participation in soil fertility research has occurred quite recently.

3 LIVELIHOODS AND THE ADOPTION OF SOIL FERTILITY MANAGEMENT TECHNOLOGIES

Low levels of adoption of agricultural research outputs have been attributed to the fact that research has failed to take into account farmer's objectives in the development of technologies. African farmers face a variety of constraints including limited access to credit, unreliable or non-existent input supply, risky and marginal production environments, poor access to markets and poor education, which entail that many small-scale producers are unable to meet their needs through simple high-input technologies (Batz and Dresrüsse, 1999). Even when farmers are convinced of the ability of a technology to increase yields, they may not adopt it due to a range of socio-economic factors (David, 1995; Moser and Barrett, 2003).

Research has been criticised for not addressing rural livelihoods in the development of technologies (Chambers, 1997). Chapter 2 discussed how multiple factors which include biophysical, socio-economic and institutional factors influence intensification of land management. The livelihoods of smallholder farmers are frequently diverse and complex. Swift *et al.* (1997) identify the irrelevance of much on-station research to the needs of farmers and the failure of researchers to recognise the heterogeneity of farm environments and socio-economic circumstances as fundamental to the low level of adaptability of resource management technology by African farmers. Heterogeneity occurs at many different levels. Agro-ecological zone, differences between peri-urban and rural agriculture, land tenure, farm sub-systems, gender, financial considerations and macro-economic and political factors all influence farmers' soil fertility management strategies in sub-Saharan Africa (Harris, 1997; Scoones and Toulmin, 1999). Technological packages do not always take into account the diversity and complexity that is found on smallholder farms, and the multitude of objectives that are balanced by different members of farming families (Sumberg and Okali, 1989). Small farmers respond better to technologies that address more than one constraint in the farming system, even if the effects on a single constraint such as soil fertility are less than those of a more targeted input (Bunch and Buckles, 1998). For instance, in the adoption of live barriers in the Colombian Andes farmers preferred to use fodder species or sugar cane rather than vetiver grass which was technically proven to be the best at erosion control (Thomas, 1997).

This chapter reports the results of an analysis of land based livelihoods at five field sites at the forest margin in Ghana. The research disaggregated farmers in terms of key social

characteristics to improve understanding of access to resources for productive agricultural activities by different groups of farmers. This was later used to assess how soil fertility interventions generated through research addressed farmers' priorities and were compatible with their circumstances. The results of the research reported here also provide important contextual information necessary for understanding the rest of the thesis.

The methods used to understand farmers' land use practices and access to resources are reported in the following section. A diagrammatic approach to mapping key information about land use and rural livelihoods, which can assist planning of agricultural research and extension, was developed during the course of this research and is described in the next section. This is followed by an overview of the ecology, agriculture and people of southern Ghana, and information on the selection of field sites. The results of the land use and livelihoods analysis are then reported, drawing attention to differences between field sites, and between different social groups of farmers. This is followed by a discussion of farmers' access to key resources for land use and soil fertility management, and an assessment of the implications for the appropriateness of agricultural technologies to the livelihoods of different individuals at the forest margin in Ghana.

3.1 Methodology

The research was carried out from 2000 to 2002 in conjunction with two projects funded by the Department for International Development (DFID): 'Bridging Knowledge Gaps between Soils Research and Dissemination in Ghana' (R7516) and 'Shortened Bush-fallow Rotations for Sustainable Livelihoods in Ghana' (R7446). This section describes the general research methods. The location and selection of the field sites are described in Section 3.3.

3.1.1 Livelihoods approaches

A livelihoods approach to development and agricultural research has recently become prominent and is being implemented by DFID in its development programmes. This commonly accepted framework views livelihoods as comprising of material and social resources or assets which are used to obtain a living. The assets are categorised as natural, social, physical, human and financial. The approach also recognises the dynamic nature of the resource base and the influence of the institutional context (social, economic, and political) in governing access to resources (Carney, 1998).

Inland livelihoods in the forest and transition areas of the south of Ghana depend predominantly on crop farming. Natural resources and more particularly land, are therefore

foremost in the livelihoods of rural people. The approach used in this study differs from the DFID approach to livelihoods in that it does not deal with all assets equally. It focuses on natural assets, as these are relevant to understanding soil fertility management. Other assets are analysed to a much more limited extent in terms of their influence on access to the natural assets.

3.1.2 Sources of data

Analyses of livelihoods based on natural resources generally draw on a variety of sources and methods (Ashley, 2000). Information on livelihoods and agricultural practises was gathered in this study using a number of different methods and including both primary and secondary data sources (Table 3.1).

Table 3.1 Methods used for gathering data for the livelihoods and land use analysis at each field site

Method	Wassa Amenfi	Atwima	Peri-urban Kumasi	Tano	Yabraso
Secondary data sources	√	√	√	√	√
Key informant interviews	√	√	√	√	√
Group meetings	√	√		√	√
Farm visits	√	√	√	√	√
Short structured interviews with approx. 40 informants	√			√	√
Structured interviews with most of the population		√		√	√
Causal diagramming	√	√		√	√
Participatory budgeting				√	
Livelihood and land use diagrams	√	√	√	√	√

3.1.2.1 Secondary data sources

In all areas, district development plans, project reports and other documents were consulted where available. Sufficient information about livelihoods and cropping practices could be gathered for the peri-urban Kumasi area from these sources so that it was not necessary to collect any further primary data. Natural resource management in the peri-urban Kumasi area has been the subject of several DFID funded projects producing ample documentation, mainly from the Kumasi Natural Resources Management Research Project (R6799) (Brook and Davila, 2000).

3.1.2.2 Key informant interviews

Key informants are individuals who are particularly knowledgeable about matters of interest to the interviewer due to their knowledge, previous experience or social status within the community (World Bank, 2002b). In Ghana the assemblyman (or assembly woman) of a village or area is the modern political head of a community. He is elected by the community

and his duty is to represent them at the District Assembly under the current decentralized democratic system of governance. His counterpart is the chief who is the traditional head of the community and the custodian of the land and other natural resources. The chief is aided by a group of elders. Past and present assemblymen, the chief and elders, well-known village farmers, ordinary village people and the agricultural staff working in the area (predominantly district staff of the Ministry of Agriculture) were interviewed to gather general information about the community.

3.1.2.3 Group interviews

Group interviews open to all members of the farming community were also used to gather general information about the community and farming practises. Focus group discussions were held with disaggregated groups of farmers to obtain different information and perspectives from different social groups within the community.

At Oda, contacts were established with the community through an existing agroforestry project whose technical employees were resident and well integrated into the community. At the other locations, in order to adhere to local customs and formalities communities were approached through the chief and/or assemblyman (depending on which individual was most visible and active and showed most interest in the research team). These contacts then organised groups for the research team to interview. It became apparent, however, that this did not always lead to participation from a broad range of community members. Most commonly, there were few women and settler farmers at these meetings, and a disproportionate number of individuals related to the person organising the meeting. False and unfounded expectations of community research and development work, and obtaining broad participation in community meetings are not uncommon problems in Ghana (GTZ/MOFA 2000a; Nieuwenhuis *et al.*, undated). Organisers of meetings may have false perceptions about what the research team can offer the community, and want their relatives to benefit. Farmers themselves may not perceive community meetings to be relevant to them, perhaps due to the way in which the information is channelled to them such as through existing political structures within the community which do not usually encourage their participation. The participation of women farmers was particularly difficult to achieve at some sites due to the extra burdens on their time (Sections 3.4.1.1; 3.4.4).

In addition to the problem of attendance at group meetings, some sections of the community, particularly women and young people, were reluctant to express their own views in front of the whole community. Older males tended to dominate the discussion in open community meetings. Therefore it was essential to hold meetings separately for different sections of the

community to gain the participation and opinions of a broader spread of community members. This was done selectively depending on the research interests and initial community participation.

3.1.2.4 Farm visits

Transect walks were carried out along routes selected in consultation with key informants to show the diversity of land use. At least two paths in different directions were walked at each site. One or several community members accompanied the researchers and provided information about the land and farms that were seen. It is customary that 'strangers' (from outside of the community) are accompanied whilst visiting a village until they become very familiar with the area and that no one enters a cultivated plot without being accompanied, or having permission, from the owner (else they may be suspected of theft or some other malpractice).

In addition to transect walks, the farms of approximately 20 farmers at each site were visited during individual interviews to elicit local ecological knowledge (Section 4.1.3.2). Sometimes the researchers arranged to accompany a farmer to their field and interview them there. At other times, where prior arrangements were difficult to make because farmers were busy or field locations distant to where the researchers were staying, farmers were located on their farms on spec and interviewed there. Farm visits and transect walks helped the researcher to understand land use, farm activities and crop rotations.

3.1.2.5 Structured interviews

Short structured interviews were carried out with about 40 farmers at Oda, Subriso and Yabraso. Farmers interviewed were chosen to represent a mixture of men and women, older and younger people, settlers and native people, wealthy farmers and more typical farmers (where these strata were present).

These interviews were used to obtain basic information about the farmers themselves including age, ethnic origin, whether native or a settler in the community, other income generating activities, livestock ownership, the proportion of crop sales and the number of plots cropped. Further information was gathered about the plots themselves including size of the parcel, land and soil type, current cropping pattern, past fallow or cultivation on the parcel and means of access to the land. Farmers were also asked about sources of labour, decision making and responsibility for crop cultivation to understand the organisation of production. The check list used forms Appendix I.

Structured interviews with the majority of individuals in the community who were farming in their own right were carried out by Obiri-Darko (2000) at three of the field sites. Whilst these were not part of this research, some of the data generated concerning land use and land acquisition is reported in this chapter (and is referenced appropriately). Statistical analysis of different categories of farmers was carried out using the Chi square test in SPSS version 11 for Sections 3.4.3.1, 3.4.3.2 and 3.4.3.3, unless another statistical method is specified.

3.1.2.6 Causal diagramming

Separate group meetings were held with disaggregated groups of farmers where participatory causal diagramming (Galpin *et al.*, 2000) was used to understand what farming constraints existed, their relative importance and their causes (Table 3.2).

Table 3.2 Causal diagramming exercises at the field sites

Field site	Groups of farmers	Crop focus
Oda	Older men	General
Oda	Younger men	General
Oda	Women	General
Gogoikrom	Settler men	General
Gogoikrom	Young men	General
Gogoikrom	Settler women	General
Subriso	Native men	Maize
Subriso	Settler men	Maize
Subriso	Women	Maize
Yabraso	Native men	Maize
Yabraso	Settler men	Yam
Yabraso	Native women	Maize
Yabraso	Settler women	Maize

At Yabraso and Subriso where a diverse range of crops are grown, some of which have their own unique problems, a crop focus was chosen in order to provide a sufficiently detailed picture. Maize was focused on in many cases as it is grown by the majority of farmers, and yam was also chosen at Yabraso as it is also very widely grown (Section 3.4.3.2). Due to women's time constraints it was often difficult to get a group together even at their own convenience. This accounts for the lesser number of diagrams drawn by women and the lack of differentiation within the stratum.

Causal diagramming was a useful means of gaining a more in depth understanding of farmers' problems. However, it is difficult to make simple comparisons from the results of the exercise as farmers responses may be biased by their prior knowledge of the focus of the origin of the researchers and the focus of the research and their expectations of what the researchers can do for them. With the group of young men at Oda this was particularly obvious, and as previously stated (Section 3.1.2.3) this is not an uncommon problem.

3.1.2.7 Participatory budgeting

Participatory budgets were constructed at Subriso to quantify and analyse resource inputs and outputs for different crops using the method of Galpin *et al.* (2000). These were done primarily to compare the resources required for different crops and their profitability. The crops chosen were maize, plantain, groundnut, yam and tomato, and an attempt was made to include the main intercrops in the budget scenario.

Budgets were constructed firstly as group exercises. However it became apparent that the estimated quantities of labour were both very variable, and sometimes very large e.g. cash estimates of the labour required to clear one acre of land varied by a factor of six (between 33 000 and 200 000 cedis). Translating labour and other inputs into cash costs reduced profit margins to small or negative amount, even under different price and labour scenarios.

As a result of this budgets were constructed with about ten individual farmers for each crop. Farmers were asked to use their existing plots and recall actual labour and cash used. Unfortunately this exercise also ran into problems. The labour used and the cost of labour varied widely, and as these were large expenditures, they had considerable influence on the final budget. Farmers' estimates of area were later found to be inaccurate (Obiri-Darko, 2003 pers. comm.). Furthermore, some crops had not yet been harvested or sold so that estimates of profitability were difficult to make, particularly as inflation was very high during the year 2000 so that comparisons with previous years would not be satisfactory. Although the figures generated by the participatory budgets are not reported, the method did serve to consolidate knowledge on the uses, required inputs, advantages, constraints and risks of different crop choices and provide a more detailed picture of farmers' activities.

3.1.3 Data reporting

Livelihood analyses for the five sites were originally reported in three unpublished project reports and one MSc thesis (Table 3.3).

Table 3.3 Original reporting of the livelihood analyses

Reference	Field sites	Type of report
Frost (2000)	Gogoikrom	MSc thesis
Obiri-Darko *et al.* (2000)	Gogoikrom, Subriso, Yabraso	Unpublished report
Moss (2001b)	Oda	Unpublished report
Moss (2001a)	Peri-urban Kumasi	Unpublished report

The main focus of Frost (2000) was local ecological knowledge, and this and the other reports were largely descriptive reporting of livelihoods at each of the field sites. This analysis

provides a synthesis of findings at all the field sites that is more critical and comparative of differences in livelihoods and their implications.

3.1.4 Stratification of livelihoods

In each location, the livelihoods of individuals were disaggregated to reflect the diversity of access to resources pertaining to that site. Categorization of different livelihoods was primarily based on the type of crop fields cultivated, differences in terms of access to land where this was relevant to agricultural intensification, and additional income generating activities. These differences were broadly associated with differences in gender, age, farmer origin and female marital status although not all factors were considered at each site (Table 3.4).

Table 3.4 Stratification of livelihoods at each site

Site	Gender	Farmer Origin	Age	Female marital status	Number of groups
Oda	√		√	√	5
Gogoikrom	√	√			4
Peri-urban Kumasi	√		√		4
Subriso	√	√			4
Yabraso	√	√			4

Gender was considered at all sites from the very beginning. However it became apparent later on during the research that not all women within each stratum such as older women, or native women, have the same access to resources. Therefore at Oda, where many married women do not farm in their own right, women were divided according to marital status. This resulted in three groups: older married women, older single women and younger women. Older single women were either widowed, divorced, or had husbands who were absent for a long time for work in other towns or countries. All younger women interviewed were married with resident husbands.

As will be seen (Section 3.3.3), the Ghanaian population is highly mobile and some settlers could be found at each of the field sites. During the research, farmer origin was broadly captured by distinguishing between native and settler farmers at those field sites where settlers formed a large proportion of the population i.e. at Gogoikrom, Subriso and Yabraso. However, this simple stratification did not always adequately capture the factors that are likely to influence livelihoods and investment in soil fertility management. Therefore, in the following sections farmers' ethnic origin or home region and their land holding status are sometimes referred to in addition to whether they were natives or settlers. At peri-urban Kumasi, differences between native and settler livelihoods were noted where these were relevant, particularly with regard to larger scale livestock enterprises and some forms of

specialised crop farming. At Oda, differences in livelihoods of the native Wassa population and settler farmers were not assessed due to the low proportion of settlers and the wealth of existing literature relating to the livelihoods of settler cocoa farmers in Ghana (Hill, 1963; Okali, 1975; 1983; Arhin, 1985).

At Oda and peri-urban Kumasi farmers were stratified according to age. Older farmers were defined as those of 35 or older, whereas younger farmers were less than 35. By this age the majority of men are married, have young children, and have started farming in earnest. Women tend to marry and have children younger than men. Child bearing and the care of young children are likely to influence women's ability to engage in farming and other income generating activities.

Overall, four or five different groups of farmers were considered at each site. Further disaggregation was limited by the time and resources available. However, this may not have been sufficient to adequately capture all differences in livelihoods. For example, there was a greater understanding of the opinions and livelihoods of young people at Oda and peri-urban Kumasi than at the other field sites. Some recommendations for future research are included in Section 3.5.7.

3.2 Development of livelihood and land use diagrams

A method of diagrammatically representing livelihoods and land use was developed during the course of this research to depict the key characteristics of typical farming systems. The main focus of these diagrams was on land use and agricultural practices. Other key elements of livelihoods that were included were sources of labour, off-farm income generating activities and non-incoming generating activities. Diagrams were drawn for each stratum within the population which had a different livelihood. Hence the diagrams provided a broad picture of access to land, labour and capital for different groups of farmers.

Diagrammatic representations of livelihoods and land use that capture key elements of typical farming systems have a number of advantages in the analysis and presentation of qualitative research. Firstly, participatory methods such as those used during this research tend to produce large quantities of descriptive qualitative data often in the form of notes from the field. Diagrams are a useful means of synthesising and presenting information in a compact form that is easily and quickly understood by others, and avoids repetition. Key facets of livelihoods and land use can be derived from visual material, and easy comparisons can be made.

Livelihood analyses are resource intensive and require strong analytical skills (Ashley, 2000). A formalised method for summarising qualitative data can be helpful. An initial attempt to represent livelihoods and land use on a diagram can help maximise the use of existing data, thus making research more cost effective and bringing greater definition to problems and questions for PRA exercises to answer. There is often some information about land use and livelihoods at a site of interest contained in existing reports and documents and the heads of local researchers and development workers. This is often an underutilised resource. Attempting to represent this knowledge on a diagram can help to focus on key elements of interest to the research.

A formalised method can also draw attention to gaps in the researchers' knowledge. This is particularly important where a variety of methods are used, frequent triangulation is required, and where the population of interest contains a number of strata. If the majority of interviewing is discursive or semi-structured it is easy for the researcher to neglect to obtain the same information from each different stratum in the community. Formalised diagrams can help organise existing information and lead to the identification of gaps that need to be filled through further targeted research.

Livelihood and land use diagrams were developed from a method of classifying land use using four different hierarchical levels developed by Sinclair (1999). The purpose of the original classification was to provide a framework for understanding the role of trees on farms and so clarify the classification of agroforestry practices. The method started off by identifying system boundaries. It then identified different categories of land with different land use potential. It went on to summarise the different agroforestry practices pertaining to each category of land. Finally these practices could be grouped together in space or time.

This original method has more general relevance to agricultural land use. It was adapted to the livelihoods focus of this research by incorporating key elements of rural livelihoods, other than land use, into the systems analysis. Hence the system boundaries were altered to encompass livelihoods rather than agricultural systems. Sources of labour were added in recognition that labour is a key agricultural resource, farmers get access to labour through a variety of means, and the labour constrained nature of agricultural economies in sub-Saharan Africa is often ignored. Off-farm income generating activities were added as these can be sources of investment for agricultural activities, and an opportunity cost of agricultural labour. Finally, non-income generating activities that support rural livelihoods but are a major and

regular opportunity cost for agricultural labour were added to draw attention to the opportunity cost of women's time.

In the following sections there will be a structured description of the key elements of the diagrams. This will start by briefly outlining land use systems, categories, practices and groups of practices as conceived by Sinclair (1999). This will be followed by more detailed descriptions of the new elements of the diagrams, namely, the livelihoods focus, sources of labour, income generating activities and non-income generating activities. Examples of diagrams for the Oda field site are presented first.

Figure 3.1 The livelihoods of older indigenous people at Oda

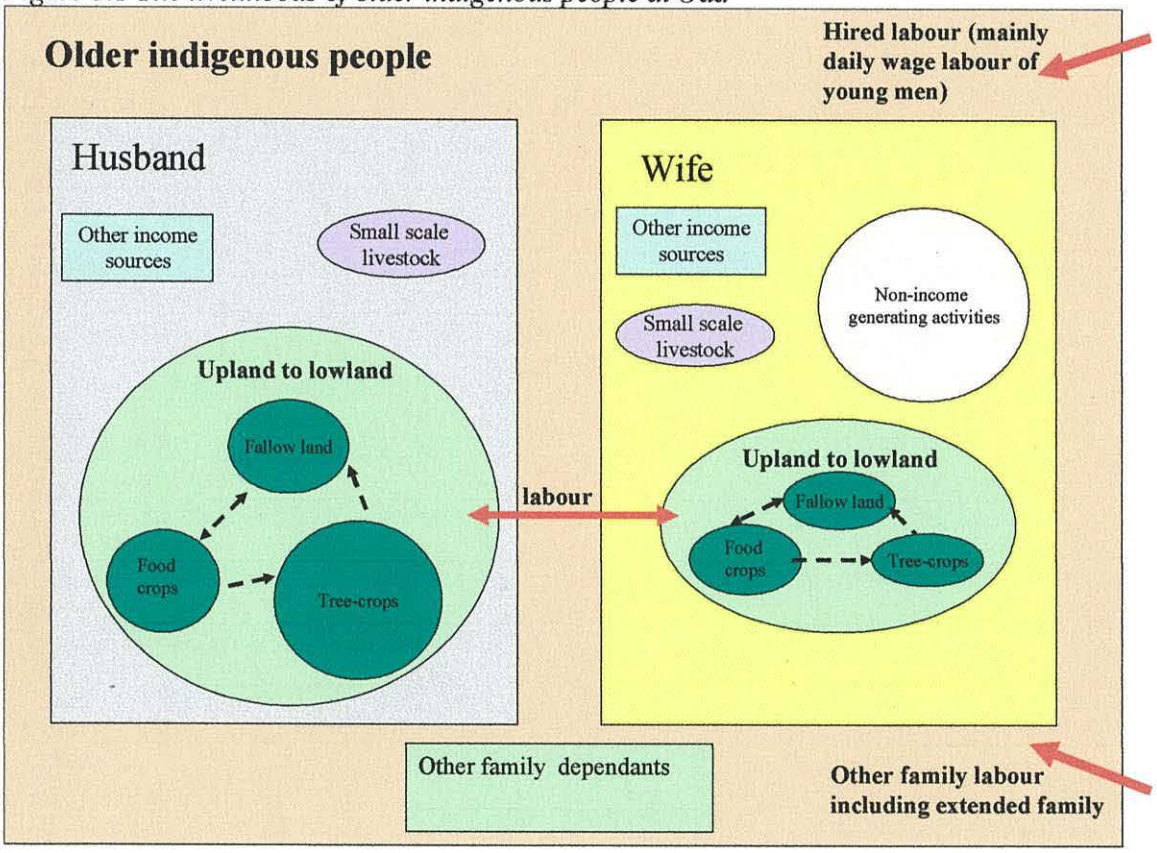


Figure 3.2 The livelihoods of older indigenous men at Oda

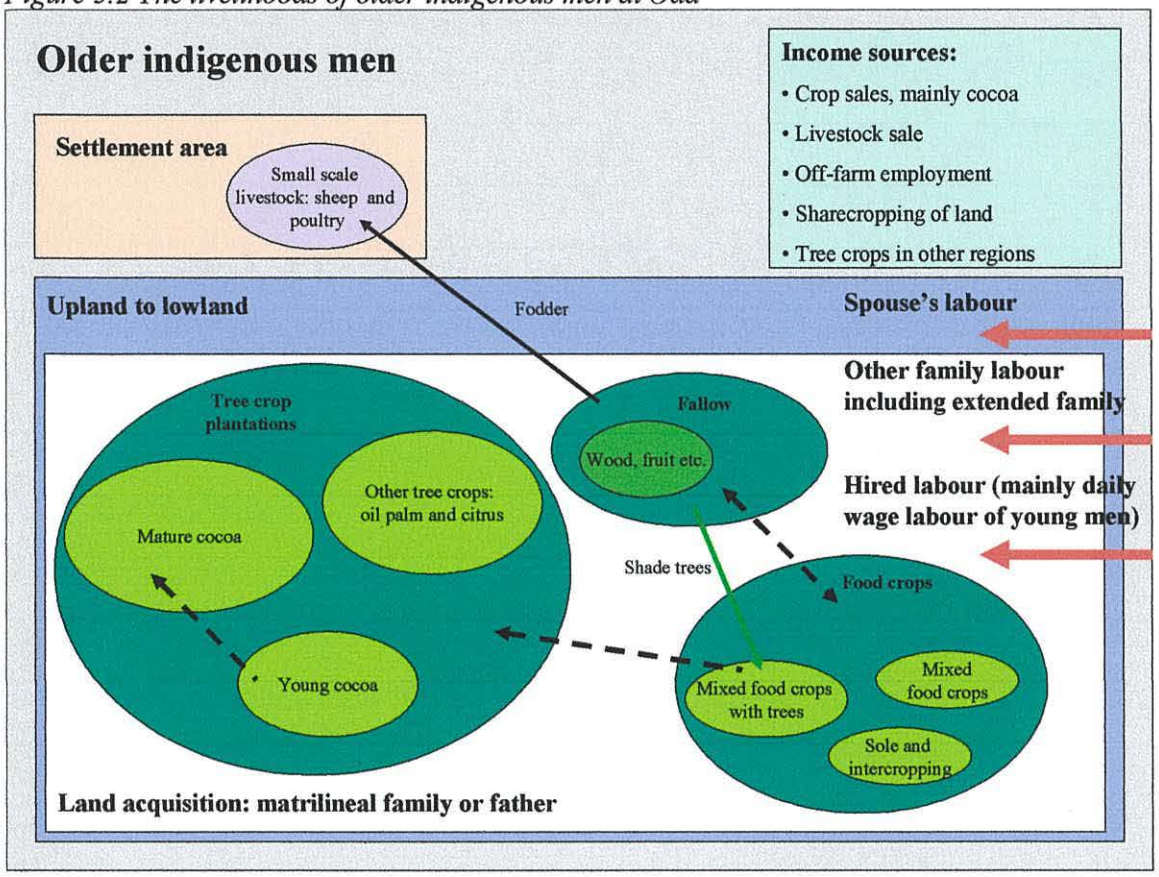


Figure 3.3 The livelihoods of indigenous wives at Oda

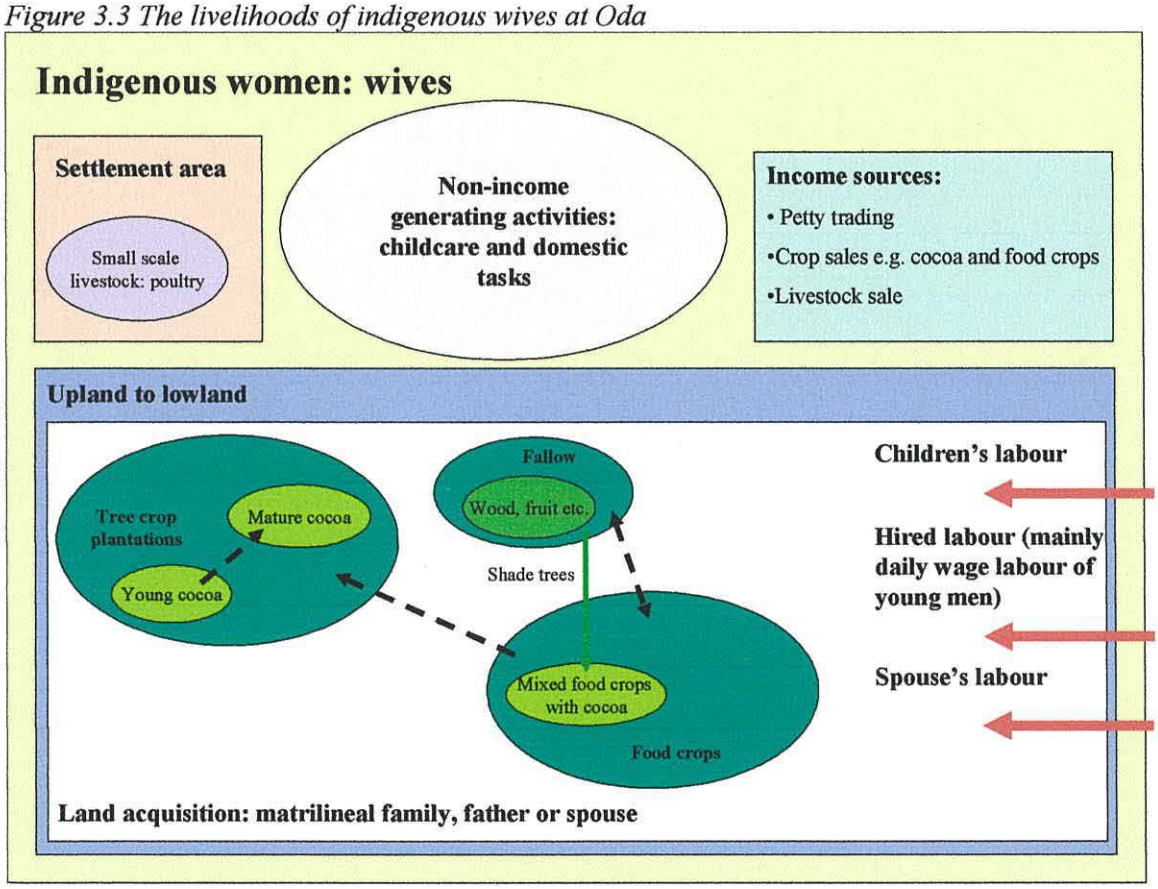


Figure 3.4 The livelihoods of indigenous divorcees and widows at Oda

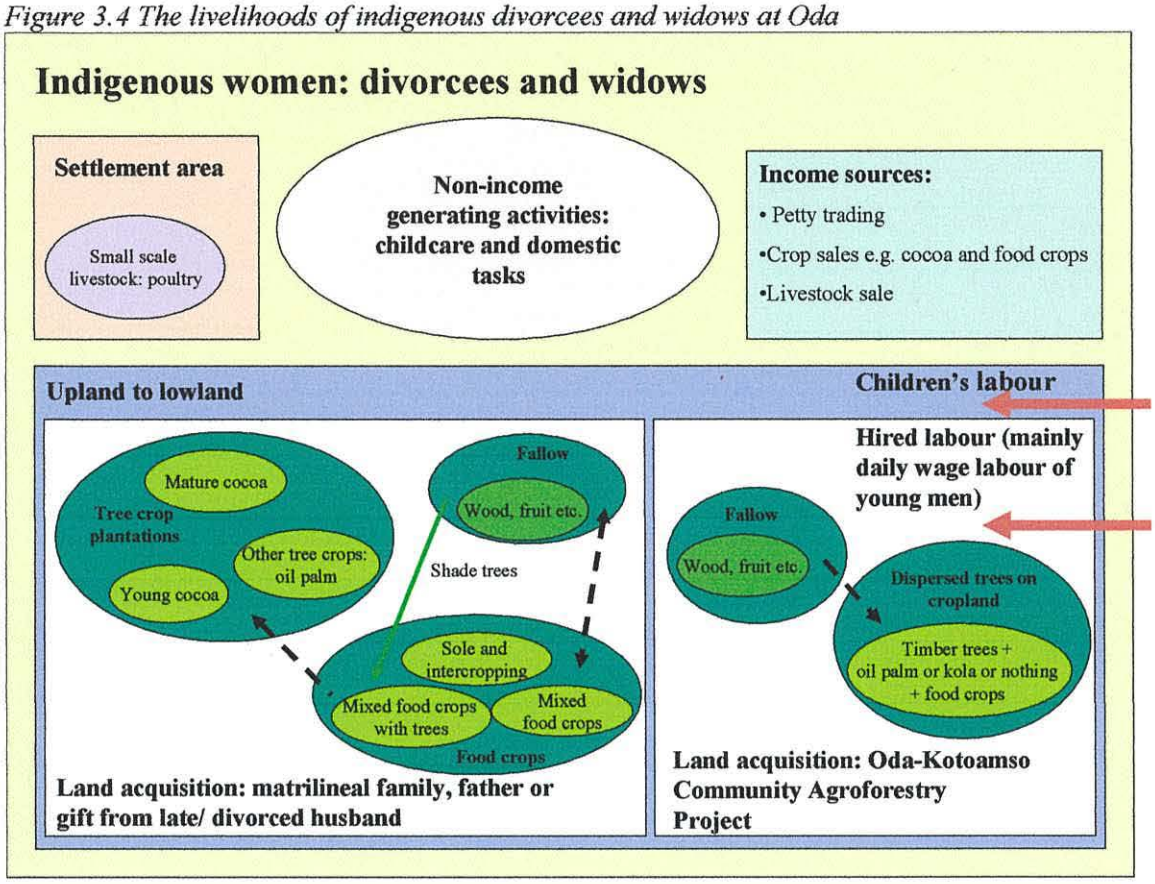


Figure 3.5 The livelihoods of younger indigenous people at Oda

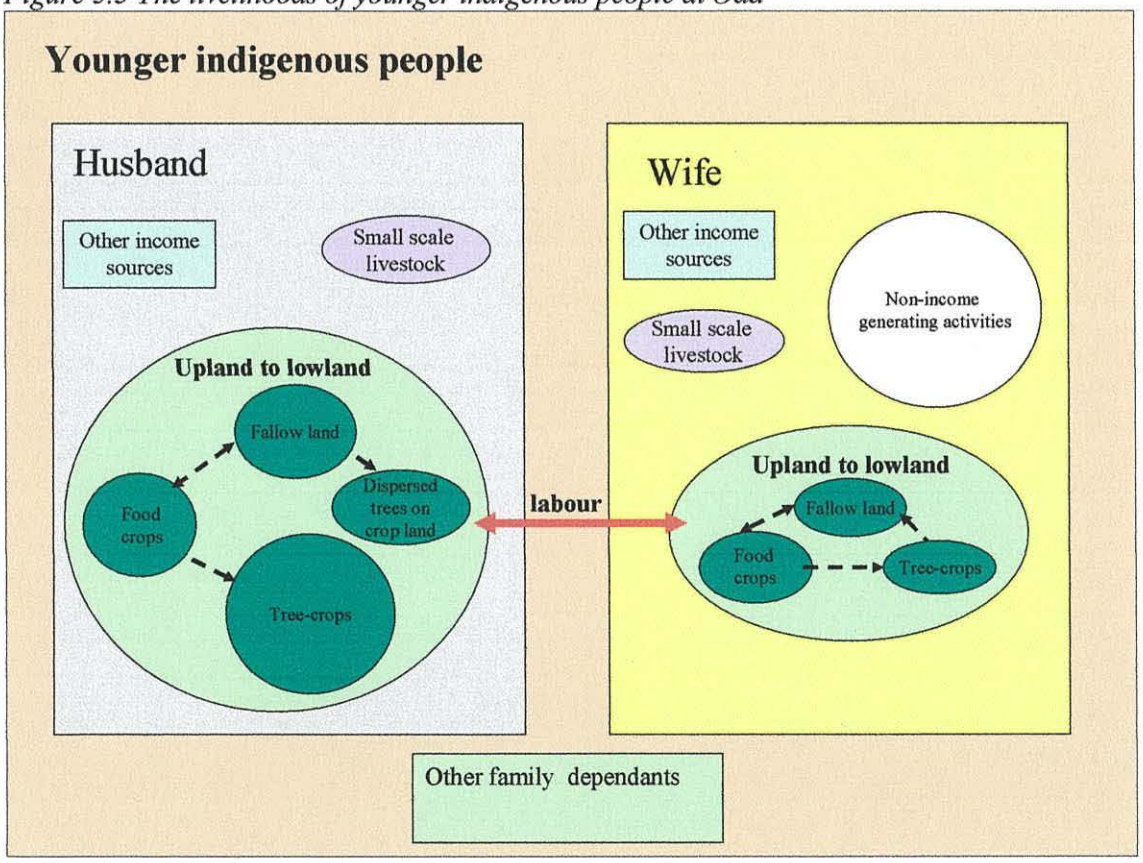
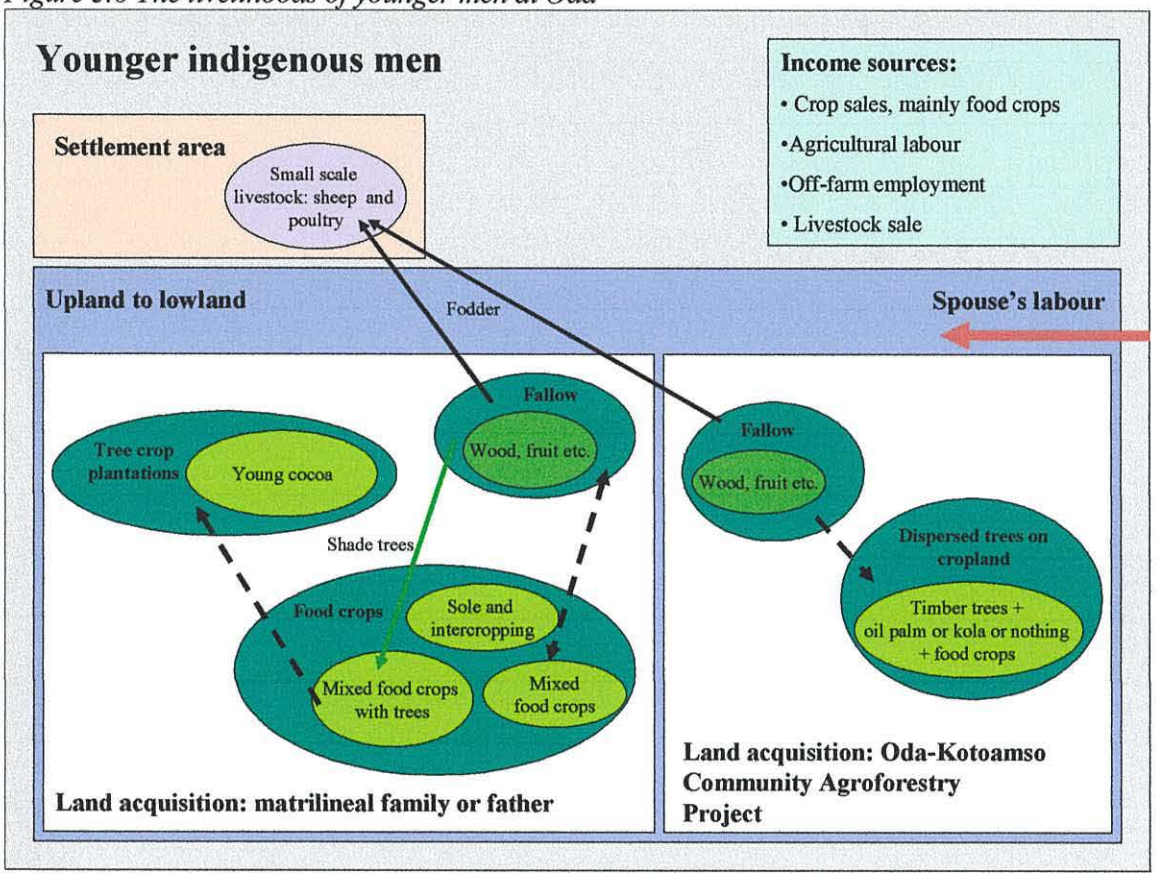


Figure 3.6 The livelihoods of younger men at Oda



3.2.1 Categorisation of land use

Sinclair's (1999) systems thinking on the organisation of land use distinguishes between four different levels: the overall land use system, land use categories, land use practices and groups of practices in space and time.

3.2.1.1 The overall land use system

Sinclair (1999) distinguishes two key aspects which are essential to a consideration of agricultural systems: holism and generalisation. Following Spedding (1979), a system is an entity which can be considered to be whole, with specified boundaries containing a group of interacting components working towards a common purpose. It is also useful to be able to generalise about groups of farm systems that are similar to one another by using a model that characterises the key features of the farms in one class. A model is a simplified representation of the real system, and is required in order to carry out useful farming systems research and make extension recommendations for groups of farms, sometimes referred to as recommendation domains (Farrington, 2000).

3.2.1.2 Land use categories: potential for land use

Land use categories are different types of land that have different agricultural potential and are used for different purposes. They are not necessarily interchangeable. Both bio-

physiological and socio-economic factors may distinguish amongst land units with different potential. Inherent land use potential is influenced by slope, aspect, access to irrigation, drainage and soil fertility. Distance from the homestead or other infrastructure is frequently important. Previous or current land usage may also influence agricultural potential. For example, forested land may have different potential than that which has been cleared of trees. Land can shift from one category to another, e.g. with investment in irrigation, or if land is planted up with trees. Land ownership is fundamentally important as the terms of access to land will influence the way in which it can be used.

3.2.1.3 Land use practices

Land use practices are discrete groups of components such as trees, animals or crops that are managed together. Monocropped maize is a simple example of a land use practice. A more complex example is a cocoa tree crop plantation, with naturally occurring forest trees which are managed to provide shade for the cocoa. Distinguishing between different practices includes consideration of their underlying agroecology and management. The type of components within the practice e.g. trees, crops and livestock and their spatial arrangement are fundamental. In agroforestry practices the type of tree cover in mixed cropping is important e.g. natural vegetation, planted forest or plantation tree crops. The predominant purpose of land usage and ownership may also be considered.

3.2.1.4 Temporal and spatial groups of land use practices

Temporal groups of land use practices include land use rotations, or changes in land use over time. A very common temporal group of practices is the cultivation of a crop followed by a fallow phase. The cultivation phase and the fallow phase can be viewed as two distinct land use practices because each phase has quite different components and different management requirements. However, together they form a group of practices because what happens in one phase affects the performance of the other. During the fallow phase soil fertility is restored and crop performance in the subsequent cultivation phase is improved.

Spatial groups of land use practices are much less common than temporal groups. They are groups of practices where the functionality of one practice is affected by its location with respect to another. For example a homegarden surrounded by a live fence forms a spatial group of land use practices. The live fence is a discrete practice as it is managed separately from the rest of the garden and has a specific function - that of protecting the garden.

3.2.2 Livelihoods focus

Bringing a livelihoods focus to land use diagrams made it necessary to redefine the boundaries of the system. The livelihood system of a household or individual replaced the original 'land use system' focus, broadening the scope to include non agricultural aspects of rural livelihoods. The livelihood system encompasses the decision making unit and so may consist of either individuals or households. The nature of the decision making unit influences the nature of access, use and control of resources and, therefore, makes different means of representation appropriate for different decision making units. Where individuals within the household have different sources of agricultural land, land is managed separately and produce may be disposed of autonomously, i.e. where a household consists of a number of different decision making units, then individual livelihoods and land use may be represented separately. For example, a strong tradition exists in Africa of separate economic spheres of activity for men and women, with considerable independence for each (Rogers, 1990).

Where individuals within one household contribute to a single farming system using a common pool of land, land use is best represented at the household level. This is common where farming activities are highly integrated. Decision making, responsibility and the labour used for different activities may be represented using annotations for different members of the household.

3.2.3 Sources of labour

Labour is a key agricultural resource. Low external input technologies frequently substitute land or capital for increased inputs of labour and even high input green revolution technologies have only taken place through the use of increased labour inputs (Lipton and Longhurst, 1989). Nevertheless, as stated in Section 2.1.3, the labour constraints of smallholder farmers are not infrequently underestimated by researchers developing soil management technologies. Labour is inherently difficult to measure (Levi and Havinden, 1982) and statements of labour demand for improved technologies are often the subjective judgements of different stakeholders.

Farmers frequently use a variety of sources of labour to complete farm tasks. Different strata of farmer often have access to labour from different sources. In Ghana farmers' access to different sources of labour is indicative of their more general resource endowments (Section 3.4.3.4). Hired labour is associated with access to cash. Use of own labour and group systems of labour sharing (*nnoboa*) require health and strength. Caretaking, sharecropping and other exchanges of land for labour are only possible amongst farmers endowed with surplus land

resources. Ability to mobilise labour from the extended family is associated with a better position in the reciprocal exchange network amongst kin and greater social status. Use of different forms of labour is indicative of negative as well as positive resource endowments. The sick or aged may be unable to farm themselves and hence exchange land for labour. The gender division of labour and the greater demands on women's time forces them to hire more labour than men. Young men are likely to have less access to their wife's labour due to child birth and child care.

Sources of labour for agricultural activities are represented on the diagram in the form of arrows. Arrows may originate within the livelihood system itself, as for example, where the livelihood activities of a husband and wife are shown, and where each provides labour on the other's fields. Arrows may also originate from outside of the boundaries of the livelihood shown, as for example, where hired labour is used on the farm.

3.2.4 Other income generating activities

Agricultural incomes are not infrequently supported by incomes from other sources, and these were taken into account in the development of the diagramming method. Ellis (1999) estimates that in sub-Saharan Africa a range of 30–50 % reliance on non-farm income sources is common. In sub-Saharan Africa reliance on agriculture tends to diminish continuously as income level rises, although elsewhere a common pattern is for the very poor and the comparatively well off to have the most diverse livelihoods, while the middle ranges of income display less diversity. Multiple income sources are common amongst urban dwellers in Ghana where trading and agriculture are the most common activities (Owusu, 2001). They are not just survival strategies but also a route for capital accumulation, and are likely to play both these roles in rural areas as well.

In parts of West Africa uncertainty in the socio-economic and natural environment means that placing too much faith in agriculture alone may not be rational and agricultural activities are only one component of the overall livelihood strategy of a household. In south-west Niger agriculture is supplemented by migration, trading and livestock rearing activities (Batterbury and Warren, 1999).

Part-time non-farm activities may supplement agricultural incomes, particularly at times of the year when there is little farm work, or during the hungry season. Non-agricultural and agricultural incomes and activities may also interact on a longer term basis whereby capital generated from one source is used to switch livelihood strategies. Capital obtained from a

non-agricultural source may be used to invest in agricultural activities, or to switch to different agricultural activities.

3.2.5 Non-income generating activities

A final element to be included in the diagrams was the addition of activities which support or sustain the household but do not directly generate food or cash income. These activities include tending husbands' fields, child care and the preparation of meals. This element was primarily added to draw attention to the fact that women's roles in Ghanaian (and many other) societies include many unpaid but time consuming activities. The opportunity cost of these activities influences the area of land that women can farm in their own right (Section 3.4.3.1) and the type of non-agricultural income generating activities that women can engage in (Section 3.4.3.6).

The demands on women's time, (together with many other inequities), typically results in their fields having lower productivity than those of men. A number of studies have shown that one reason for women's lower productivity, when land quality has been taken into account, is that women have to put in labour on men's plots, before working on their own. Other studies have shown that women farmers would make large productivity gains if they had access to the same resources as men and this is one reason for including a gender element in agricultural development projects (Peña *et al.*, 1996; Quisumbing, 1996).

3.3 The agro-ecological context of the forest margin in Ghana and the selection of field sites

This section presents the agro-ecological context in which field sites were selected for research by reference to secondary sources. An overview of characteristics of the rainfall, vegetation, topography and soils of this humid to sub-humid region is given first. This is followed by an outline of the smallholder crop production sector, drawing attention to recent historical trends in crop production, and differences between regions. Population density, ethnic and linguistic diversity and the high mobility of the population is then outlined. The final part of this section describes the selection of field sites and provides a brief overview of their characteristics.

3.3.1 Climate, vegetation and soils

The forest and transition zones have a humid to sub-humid climate. Rainfall is bimodal with a major wet season extending from March to July and a shorter minor wet season from

September to November (Walker, 1962). Average annual rainfall varies from 1100 mm to over 2000 mm (Figure 3.7) providing a growing period of 180 to 330 days (SRI, 1999a). The wettest areas are in the extreme south-west of the country. The rainy season becomes shorter and rainfall more variable the further north you get. In the guinea savanna rainfall is unimodal. Mean annual temperatures throughout never fall below 25°C (Walker, 1962).

Rainfall in Ghana and West Africa more generally has long been known to be variable, both in the more arid northern parts of the region and in the humid south. However the variability is generally greater and better recognised in the more arid areas, as people in the humid south are less vulnerable due to their ability to harvest more than one crop a year (Baker, 2000; Walker, 1962). In line with differences in annual rainfall are differences in vegetation which ranges from rain forest to sudan savanna. (MOFA 1998; Figure 3.8).

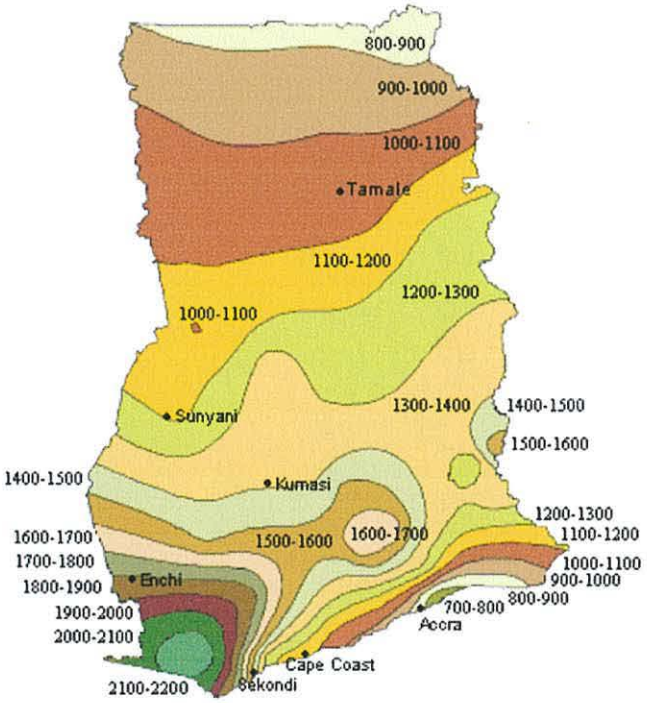


Figure 3.7 Average annual rainfall (mm) (FAO 2002a)

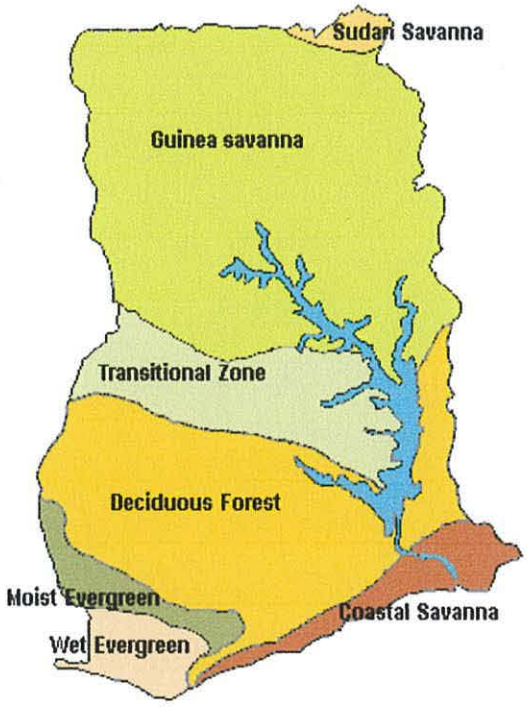


Figure 3.8 Ecological zones of Ghana.(FAO 2002b)

Within southern Ghana the forest zones have been further subdivided on the basis of the original floristic composition of the vegetation (Hall and Swaine 1981; Figure 3.9). In the dry forest the upper canopy is thinner than in the moist forest and the understorey has a much denser growth of herbaceous shrubs and climbers. Forest and woodland areas are commonly intermixed with patches of grassland. In the dry semi-deciduous fire zone naturally occurring bush fires are common and are a hazard for standing crops in the dry season. The vegetation is

dominated by fire resistant trees with a more open canopy. The savanna forest mosaic blends into the savanna with forest vestiges confined to valley bottoms, stream courses and the summits of hills (Amanor, 1996).

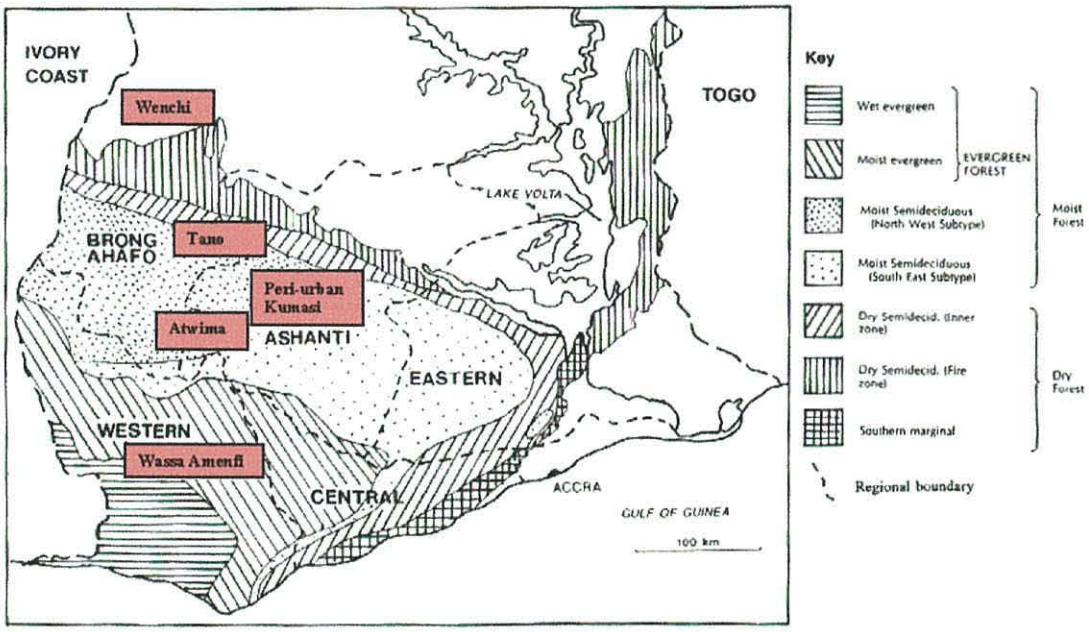


Figure 3.9 Location of the five field sites within the forest zones of Ghana (Map source: Hall and Swaine, 1981)

Throughout the forest zone most large areas of trees have been felled and there is little forest left outside of the Forestry Department reserves. Ghana is host to the Forest Pockets Benchmark for the Eco-regional Programme for the Humid and Sub-humid Tropics of Sub-Saharan Africa (EPHTA) so named because of the fragmented nature of its remaining moist forest (IITA, 1999). The present research focused on farmers living at the forest margin and spanned the moist evergreen forest, through the moist and dry semi-deciduous forest types to the northern boundary of the semi-deciduous forest fire zone and the guinea savanna where varying degrees of tree cover remain (Figure 3.9).

Ghana is a low lying country with less than 10% of the land above 300m. The topography is gently rolling to undulating with rounded hills rising to 300m in the semi-deciduous forest (Bonsu *et al.*, 1996). The forest zone has a complex geology with large areas of granite intrusion. The ancient and mixed rock types provide a great variety of chemical constituents to enrich soils (Bates, 1962).

Soils of the forest and transition zones consist of Acrisols, Ferrasols, Nitisols, Lixisols, Luvisols, Plinthisols, Cambisols and Gleysols (MOFA, 1998). The major soils in the semi-

deciduous forest zone are Acrisols, Nitisols and Gleysols. They are imperfectly to moderately well-drained with satisfactory water holding capacity. They contain medium to high organic carbon levels when uncropped. In the moist forest Acrisols and Ferrasols dominate. They are light to medium textured, highly weathered, heavily leached and acidic with low cation exchange capacity and exchangeable bases, and high Al and H ion content providing limitations for cultivation. In the forest savanna transition zone where Lixisols and Cambisols occur extensively with Eutric Nitisols in places, most soils have sandy to medium fine texture, and are moderately deep to deep. Drainage varies from low to high, depending on the presence or absence of ground water laterites (Bonsu *et al.*, 1996). Savanna soils are relatively less acid but with a slower accumulation of organic matter imparting a lower fertility status compared to soils in the semi-deciduous forest zone (MOFA, 1998). The major soil limitations to cultivation are, therefore, low cation exchange capacity in areas of higher rainfall, low organic matter under savanna conditions and decline in organic matter under continuous cultivation in the forest zone.

3.3.2 Agriculture

Cocoa (*Theobroma cacao*) has been, and still is an important cash crop, export earner and source of revenue for the Government of Ghana. Until 1976 Ghana was the world's biggest exporter of cocoa (FAO, 2002c) and cocoa remains one of the country's biggest export earners. Cocoa was first introduced into the Eastern region of southern Ghana at the end of the nineteenth century. From there, with the infrastructural development of the country and the aid of migrant labour and pioneer settlers, it spread to the Ashanti and Brong Ahafo regions and was accompanied by forest felling. The Western and Central regions of the country were opened up for cocoa in the 1960s. Cocoa swollen shoot virus (CSSV), black pod (*Phytophthora spp.*), mirids (Heteroptera: Miridae), falling producer prices and the drought and bush fires of 1983 have reduced the area of cocoa as farmers have turned to other crops, particularly in the oldest and most accessible cocoa areas (Amanor, 1994). Cocoa now only remains dominant in the western most parts of the country where forest cover still remains, bush fires do not reach and market access for food crops remains limited. Oil palm (*Elaeis guineensis*) and citrus (*Citrus spp.*) are additional tree crops grown by smallholders for cash income in the forest zone (Figure 3.10).

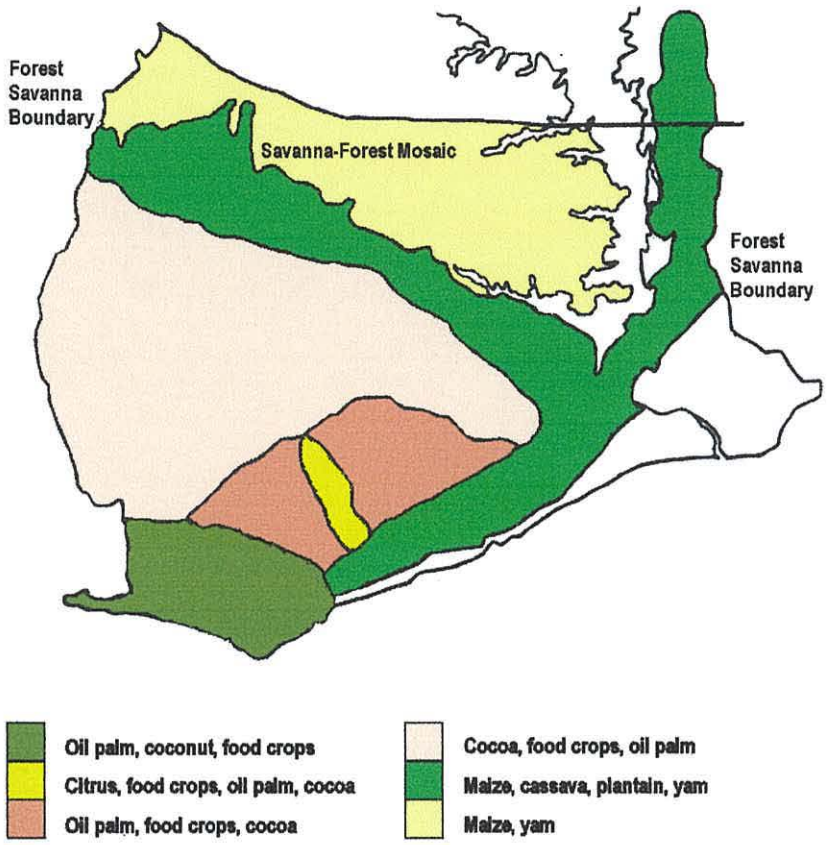


Figure 3.10 Dominant crop production in the forest and transition zones of Ghana (Amanor, 1996)

The Government of Ghana is trying to encourage the expansion and diversification of the export market for agricultural commodities (MOFA, 2000). Within the crop sector pineapple (*Ananas comosus*) has been perhaps the most successful non-traditional export since structural adjustment which commenced in 1983. However, the demands of the European export market for fresh fruit and vegetables are difficult for smallholders to meet and the majority of exported pineapples come from the large plantations of non-resident commercial farmers and producer-exporters (Takane, 2002). This is in contrast to the case of cocoa where smallholders have an advantage. Higher prices are paid for Ghanaian cocoa on the world market due to its superior quality which is an outcome of smallholder production (Amoah, 1998). Pineapple production is limited to the coastal peri-urban areas which are close to domestic urban markets and export and juice companies. Other non-traditional export crops are palm oil (*Elaeis guineensis Jacq.*), banana (*Musa paradisiaca var. sapientum*), pawpaw (*Carica papaya*), fresh yams (*Dioscorea spp.*), shea nut (*Vitellaria paradoxa*) and coffee (*Coffea canephora*) (MOFA, 2000).

A range of food crops are grown in the forest and transition zones for home consumption and as cash crops for the domestic market. Food staples of the forest zone are plantain (*Musa paradisiaca*), cassava (*Manihot esculenta*) and cocoyam (*Xanthosama sagitifolium*). Oil palm is the second most important tree crop. Maize (*Zea mays*) production has risen in forest areas since the bush fires of 1983 and has become an important cash crop. In the more transitional areas a wider variety of crops is grown including groundnuts (*Arachis hypogaea*), yam and horticultural vegetables. The northern parts of the Brong Ahafo region are a major food producing zone. They supply urban markets and produce is also transported to neighbouring countries (Amanor, 1994).

Agriculture and land use in peri-urban areas can be quite different to that in rural areas, and urban centres can have an extensive influence. Within the Ashanti region, the second largest town in Ghana, Kumasi, influences land use patterns over much of the region. The peri-urban zone extends unevenly as far as 40 km from the city centre (Brook and Davila; 2000). Within the peri-urban zone there is competition for land and labour between agricultural and non-agricultural uses. Farming systems differ in response to greater infra-structural development, urban markets and less secure land access for long term agricultural investments. In peri-urban Kumasi this results in more commercial vegetable production than in adjacent rural areas, specialised cropping for the urban snack market, higher numbers of livestock and fewer tree crop plantations as a result of less secure long term land access.

Smallholder farmers on family operated farms dominate agriculture in Ghana producing 80% of total agricultural production. Only some industrial crops such as oil palm, rubber and pineapples are produced on large corporate-managed estates although smallholders also produce significant shares of these crops (MOFA, 1999). Farmers commonly cultivate less than two hectares (Table 3.5; MOFA, 1999). Men generally cultivate larger areas in their own right than women (Amanor, 1996; Okali and Sumberg, 1999). Land holdings are also larger in the remoter cocoa growing areas with lower population density such as the Western region in comparison with the longer settled areas of higher population density such as the Ashanti and Eastern regions (Amanor, 1996; Table 3.5).

Table 3.5 Size of land holdings in the Western, Ashanti and Brong Ahafo regions

Region	**Size of holding (ha)**		
	Less than 1.2	**1.2 – 2.0**	**More than 2.0**
Ashanti	72%	22%	6%
Brong Ahafo	55%	32%	13%
Western	52%	32%	16%
Mean for whole of Ghana	60%	25%	15%

Source: MOFA (1999)

Individual farmers frequently cultivate more than one plot of land at the same time in different locations. Mixed cropping and intercropping are common with monocropping only used for more specialised cash crops and perennials. Cropping practices are non-mechanised, zero tillage and slash and burn. Soil mounding or ridging are used only for yam, groundnut and some vegetable crops and inorganic inputs are used only on highly commercialised crops.

Livestock in the south of Ghana are not well integrated into cropping systems. Sheep, goats and poultry are kept in low numbers in rural areas. Farmers consider themselves as cultivators and livestock care is minimal.

3.3.3 Population

Since colonial times, the coastal and forest areas of Ghana have benefited from greater development than the north of the country in order to exploit mineral and timber resources and the agricultural export opportunities of the humid south (Thomas, 1973). Population density is, therefore, higher in the forest, transition and coastal areas than the savanna. The older settled areas with higher infrastructural development of the Ashanti and Eastern regions have higher population density than the Western and Brong Ahafo regions (Table 3.6).

Table 3.6 Regional population density

Region	Population density
Greater Accra	897
Central	161
Ashanti	131
Eastern	109
Upper East	104
Volta	78
Western	77
Brong Ahafo	46
Upper West	31
Northern	26
Ghana	77

Source: Based on Ghana Statistical Service, 2000 Census (Provisional figures)

The population is ethnically and linguistically diverse. The forest and transition zones are home to Akan and Brong ethnic groups, although a large number of other ethnic groups are also found due to the high levels of migration within the country (Ghana Statistical Service, 2000).

Both urban and rural Ghanaians are highly mobile. It is estimated that 52% of the population do not reside in their place of birth (Ghana Statistical Service, 2000). Rural-rural, urban-urban, rural-urban and urban-rural are all common forms of migration. Different forms of

migration are undertaken for different reasons, and are associated with different locations, times and people.

Both rural in-migration and out-migration have occurred in response to agricultural opportunities. Rural-rural migration played an important role in the expansion of cocoa farming and hence the opening up of the forests and colonization of new areas in southern Ghana. It involved land purchase and sharecropping by migrants from southern Ghana with northern migrants rarely becoming land holders (Hill, 1963; Arhin, 1985).

However the use of northern labour in developing the south of the country has long been important (Thomas, 1973). During colonial times the introduction of taxes forced people from the north to look for work in the south. Northerners worked on cocoa farms as caretakers and labourers. In more recent times annual, semi-permanent and permanent migration has been significant in bringing farmers from the northern parts of the country to work as agricultural labourers and to settle, particularly in the Brong Ahafo region.

Net out-migration due to population pressure has also been occurring from rural districts which have been settled for a long time such as some of the coastal districts and parts of the Eastern region (Addae-Mensah, 1986).

Addae-Mensah (1986) explains the country's high mobility as economically motivated labour migration. However, Ghana Statistical Service (2000) claims that only 28% of migration occurs for people's own or their spouse's employment, 14% for marriage and 45% for other family reasons. These include disputes and famine. It is possible that the high proportion in this latter category is due to differences in interpretation of the survey categories for example migration due to famine could also be seen as migration for employment. Alternatively, it is possible that an individual may have both economic and domestic reasons for migration, but that the importance of family matters in stimulating migration is under recognised.

Households in Ghana have been defined as persons living together and sharing the same catering arrangements (Ghana Statistical Service, 2000). They may be polygamous, and, or include extended family members. Fostering in and out of children, usually with other relatives, is a common child rearing practice. Many children spend at least a part of their childhood in a household away from their biological parents (Stephens, 2000).

Approximately one third of all households in rural southern Ghana are female headed (Ghana Statistical Service, 2000). The average age of female household heads is greater than their

male counterparts. This may be partly due to the greater longevity of women, but may also be because older women are less likely to find another partner after divorce or widowhood than older men.

The burden of household chores (collecting wood, fetching water, child care, sweeping, rubbish disposal and cooking) falls mostly on women (Ghana Statistical Service, 2000). These chores consume a considerable amount of time with an average total for those tasks listed above of over seven hours per day for women in Ghana (although some tasks, particularly child care, which takes over three hours, may be carried out simultaneously with other tasks). Children of both gender also contribute substantially to household chores, particularly fetching water and garbage disposal.

3.3.4 Field site selection

Five field sites were selected to provide a contrast in agro-ecology, livelihood strategies, soil conditions, market access and population density (Figure 3.11, Table 3.7). Four of the sites were wholly rural in nature whereas one was located in the peri-urban zone around Kumasi. Two sites were located in the Brong Ahafo region, two in the Ashanti region and one in the Western region.

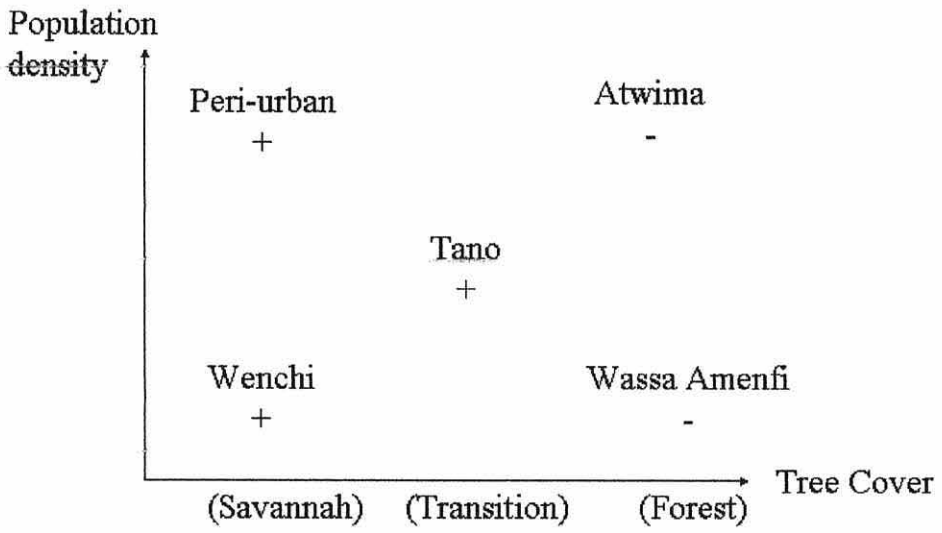


Figure 3.11 Population density, tree cover and market access at the five field sites (+ and – indicate high and low access to markets for the sale of food crops)

The villages where research work took place were selected following discussion with district staff from the Ministry of Food and Agriculture and visits to a number of villages in each area where basic information concerning the structure of the community, the livelihoods of the

people and the crops grown was collected. Contrasting locations were chosen spanning variation in key drivers of rural livelihood strategy: population density, remaining tree cover and market access. Both sites with low market access also had high tree cover reflecting the association between these factors in the region where tree cover remains in more remote areas. The villages that were chosen were Oda-Kotoamso in the Wassa Amenfi district, Gogoikrom in the Atwima district, Subriso No. 3 in the Tano district and Yabraso in the Wenchi district.

Table 3.7 Characteristics of the five field locations.

Characteristic	Wassa Amenfi	Atwima	Peri-urban Kumasi	Tano	Wenchi
Region	Western	Ashanti	Ashanti	Brong Ahafo	Brong Ahafo
District	Wassa Amenfi	Atwima	Ejisu Juaben, Kwabre, Atwima[3]	Tano	Wenchi
Dominant income generating activities	Farming	Farming	Off-farm activities growing in importance with increasing proximity to Kumasi	Farming	Farming
Percentage of labour force engaged in agriculture in the district[4]	86%	67%	37%	64%	>80%
District population density (people km^{-2}) [5]	50 (low)	120 (intermediate)	>120 (high)	89 (intermediate)	45 (low)
Access to market for food crops	Intermediate to low	Intermediate to low	High	Intermediate to high	Intermediate
Length of growing period (days)[6]	270 - 300	240 - 300	240 – 270	210 - 240	180 - 210
Average annual rainfall (mm)[7]	1680	1153	1267	1138	1188
Ecological zone[8]	Moist evergreen forest	Moist semi-deciduous forest	Moist semi-deciduous forest	Dry semi-deciduous forest	Dry semi-deciduous forest to Guinea savanna woodland
Predominant soil types[9]	Ferric acrisols with some Dystric Fluvisols	Ferric acrisols	Ferric acrisols	Ferric acrisols with some Galic arenosols	Galic arenosols

[3] These are only the districts in which the fieldwork took place. The peri-urban Kumasi area extends into additional districts.
[4] 1996 figures taken from District Development Plans: Government of Ghana (1996a); Government of Ghana (1996b); GoG/Tano District Assembly (1996); Government of Ghana (1996c). Peri-urban Kumasi: Brook and Dávila (2000) from a survey of eight peri-urban villages within 25 km of Kumasi.
[5] *Ibid* 1996 estimates
[6] SRI (1999a)
[7] Sources: Enchi meteorological station 1996 – 2000 (Wassa Amenfi), Nkawie meteorological station 1991 – 1997 (Atwima), Kumasi meteorological station 1991 – 2000 (peri-urban Kumasi), Bechem meteorological station 1991 – 2000 (Tano), Wenchi meteorological station 1991 – 1999 (Wenchi).
[8] Hall and Swaine (1981)
[9] SRI (1999b)

3.4 Livelihoods and land use at the field sites

In this section the livelihoods of disaggregated groups of farmers at each of the five field sites are outlined, compared and contrasted. The livelihoods of farmers at each field site have been reported in greater detail elsewhere (Section 3.1.3), and this analysis will focus on aspects which have a direct or indirect bearing on the management of soils. The analysis starts off by setting out how differences in gender and age influence access to resources within the social setting of southern Ghana. This is followed by a summary of the key features of locations and livelihoods for each of the five field sites. These summaries include information about the history of settlement at each location, the size and origins of the population and the implications for access to resources. They also provide information on infrastructural development, and the economic opportunities available at each site. These summaries are followed by information on agricultural activities across the field sites, including land use, crops cultivated and access to labour and markets. This is followed by information on additional income sources, and a summary of additional daily activities that may form an opportunity cost on the time and labour available for agriculture.

3.4.1 Social and cultural differences and their influence on access to resources

Akan society has been the subject of a number of anthropological studies. The understanding of gender and age that is presented here therefore draws on Oppong (1981), Okali (1983), Baden *et al.* (1994), Clark (1994) and Egyir (1998), as well as on observation and interviews during the field work.

3.4.1.1 Gender

The rules of inheritance and the traditional and accepted roles of men and women amongst the Ashanti and other ethnic groups in southern Ghana determine access to and control over resources. These had some similar influences across the five field sites. Three general aspects of social organisation combine to determine resource allocation between men and women.

Firstly, the Ashanti and other Akan ethnic groups practice matrilineal inheritance and descent (except for the Akuapems who are patrilineal). Men and women therefore frequently belong to two different types of families – a matrilineal family (*abusua*), and a conjugal family (husband, wife and offspring). An individual often has responsibilities to both. Through the matrilineal inheritance system property passes from a man to his male maternal relatives (i.e. his sibling's sons). Women inherit from other women such as grandmothers and mothers.

Within the marriage men and women play different roles. Men traditionally maintain control and responsibility for financial resources whereas women are responsible for reproduction and domestic activities. At Oda it was said that men were responsible for providing shelter for the family and making other large expenditures such as school and hospital fees. Men also handed over 'chop money' to their wives on a daily basis which was used for the purchase of food stuffs for them and their dependants. However 'chop money' and male financial contributions to household support were not infrequently a source of complaint amongst women as some men drank, others had girlfriends, and others gave up providing chop money after they had handed over a part of their cocoa plot to their wife.

Married women are considered to be dependent on their husbands. Within the marriage a woman's services to her husband include cooking, cleaning, washing clothes, bringing bath water, sleeping with him, and working in his fields. Women are also responsible for taking care of the children. Although men claimed that it was their responsibility to provide food for the family, this role was clearly frequently shared between men and women. Women with their own fields are under pressure to provide food stuffs for the household, women whose husbands have given up providing for them and their children must do so themselves, and it was said that when food and cash was scarce, such as in the lean season, it became the woman's responsibility to provide food for the family. However men also felt under pressure to provide for the family, and claimed that their wives could divorce them if they could not provide sufficient support.

Husbands and wives frequently maintain separate economic spheres of activity and keep their finances apart. Although men are seen as the main breadwinners, women also like to have their own independent source of income. Female income is used in the daily struggle to provide adequate care for themselves, their children and even their husbands. Female owned assets such as cocoa farms are also a strategy for security in the face of the possibilities of widowhood, divorce, illness and male irresponsibility or bad luck. For a woman to rely on marriage for security is seen as foolish due to the frequency of these occurrences. Traditionally the lineage is seen as a stable structure whereas marriage is considered to be more transitory.

In accordance with the principle of maintaining separate finances, husbands and wives also farm separately. Although wives provide much labour on their husband's fields, and may market the produce for him, they do not control the income from crop sales and the husband is

the main decision maker. Similarly, husbands do not control income that comes from a wife's own fields.

3.4.1.2 Age

With age comes increased access to resources – both as a result of an individual's own enterprise but also in terms of resource allocation from the matrilineal family. Age also brings increased responsibilities as men both acquire a conjugal family, and once economically active, are expected to contribute to the matrilineal family. Exchanges are to some extent based on reciprocity. An individual who has contributed to the matrilineal family in the past is more likely to be treated well and have his requests heard by his kin, than one who has not.

Unlike for men, women's responsibility for the care of others starts early and precedes marriage due to the gender division of domestic work in the household (Okali and Sumberg, 1999). Although both male and female children participate in domestic chores, as boys get older their participation declines, whereas girls continue to be responsible for the welfare of others at home.

3.4.2 Population and characteristics of each field site

Each field site had its own characteristics in terms of the origins and movement of its population, its history, environmental problems and the economic opportunities afforded its population by way of its location. The main distinguishing features of each field site are outlined in this section.

3.4.2.1 Oda

The southernmost and wettest field site, Kotoamso Oda (otherwise known as Oda), was located about 10 km to the north-west of the district capital of Asankrangua on an unsealed road in the Wassa Amenfi district. The village had long been settled and the population was around 2000 people. The population was dominated by native Wassa people, who form a part of the larger Akan ethnic group. There was only a very small settler population residing in the village itself (less than ten percent of the population), although other settlers inhabited nearby hamlets. The dominant activity was the cultivation of cocoa.

Despite the sparse population density in the Western region, much of the original forest at Oda and the surrounding settlements had already been cleared by the 1950s prior to the expansion of cocoa (Ahn, 1961), and land for cocoa farming had, therefore, now become scarce. As with other areas of the Western region the road network and quality of the roads in the district were very low limiting the market potential for cash crops other than cocoa

(Government of Ghana, 1996a; Siaw *et al.*, 1999). In addition to cocoa farming, the mining and timber industries were important sources of employment in the area and attracted migrant workers (Government of Ghana, 1996a). However, many young people left the village to look for opportunities in urban centres.

At Oda, investment within the village in off-farm income generating activities to support farm incomes was much more apparent than at any of the other field sites. The main street had many thriving non-agricultural trading and business activities, including eleven general goods shops or kiosks, in sharp contrast to the other locations. At Gogoikrom, the smallest village, there was one general goods kiosk, but at Subriso, the largest, there were none. The presence or absence of these kiosks and other visible businesses was probably a function of a village's location and the characteristics of its population. Oda was larger than Yabraso and Gogoikrom and had close links to other villages and hamlets that could not be reached by road. Although it was only 10 km from the district capital and closer to the nearest small town, unlike Subriso and Yabraso, it was located at the end of a motorable road, rather than on a main bus route. Furthermore, although many of the young people in the village were migrating in search of off-farm employment, it was not uncommon to find older people who had worked elsewhere in southern Ghana in mining, forestry or urban centres, returning to the village having accumulated some capital. Cocoa farming in old age may be considered a much more attractive prospect than food crop farming, and establishing cocoa farms was said to be a strategy for support in old age in southern Ghana. However, this has not stopped out-migration to urban centres from other cocoa villages such as Gogoikrom. Another difference between Oda and the other field sites was in the homogeneity of the population. At the other rural field sites, there were large proportions of settlers amongst the population who used income from farming to support livelihoods elsewhere in their home towns, and at Gogoikrom absentee land owners also used the profits from cocoa farming to invest in urban livelihoods. Although young people at Oda were migrating to urban centres, it is possible that more of the income from agriculture was remaining in its place of origin than at the other field sites and that farmers were investing the profits of farming in livelihoods in the village rather than using them to migrate to urban centres or support livelihoods and families elsewhere.

3.4.2.2 Gogoikrom

Cocoa was also the most important cropping activity at Gogoikrom in Atwima district. The village was situated in the moist semi-deciduous forest zone, about 50 km from Kumasi, the last 10 km on an unsealed road. It was originally settled in 1930 and was relatively small compared to the other rural field sites, comprising only about 500 people (Obiri-Darko *et al.*, 2000).

The population was characterised by a large number of absentee land owners who lived in large towns, and used sharecroppers and caretakers to establish and maintain cocoa farms. Many of these land owners had inherited, rather than established these farms themselves. Settlers outnumbered native farmers due to the presence of the descendants of past in-migrant Ashanti settlers from the Kwabre area, recent settlers from the north of the country and out-migration of the native population. Land owners included both the natives of the area, and the descendants of the in-migrant Ashanti settlers. In addition to cocoa, lowland rice (*Orzya sativa*) was an important cash crop cultivated by the northern migrant settlers in valley bottom areas (Obiri-Darko *et al.*, 2000).

3.4.2.3 Peri-urban Kumasi

Kumasi is the second largest city in Ghana. It is located in a central position in the country and is an important trading centre. Peri-urban Kumasi has been described as dynamic in time and space as villages are in transition from rural to urban status (Blake *et al.*, 1997). Peri-urban villages had characteristics quite different from the other rural field sites. The demand for land for commercial, industrial and residential development led to shortages for agriculture and long term tenure insecurity. Power over the disposal of land was vested in the chief so that land was taken over for development without consultation of the families who had been farming it for centuries (Brook and Dávila, 2000).

Land shortages and the economic opportunities offered by the proximity of the city meant that many people were either moving out of farming, or else combining farming with other occupations. Only 37% of the labour force in eight peri-urban villages were full-time farmers compared to between 64% and 86% in the rural districts (Government of Ghana, 1996a, 1996b, 1996c; GoG/Tano District Assembly, 1996; Brook and Dávila, 2000). Older women were more likely to remain in farming than other categories of the population.

The proximity of Kumasi provided the best opportunity for the acquisition of agro-chemical inputs and for the sale of food crops and livestock products of all the five sites. Cash cropping of short duration crops such as vegetables, maize and rice was more intensive than in rural areas. Livestock production (poultry, cattle, pigs, sheep and goats) took place on a larger scale, but remained little integrated with crop farming. Despite increasing pressure on land, the traditional food crops of plantain, cassava, cocoyam and maize were cultivated under the traditional minimum input bush fallow system. There were few tree plantations due to competing land uses and the lack of long term secure tenure. The pressure on agricultural land

had resulted in a low level of tree cover and increasing grass invasion in comparison to the rural field sites.

Peri-urban villages had a more socially and economically diverse population than the rural field sites. In-migration was occurring for residential purposes by those working in Kumasi as well as for farming of specialist crops such as rice and other economic opportunities within the village. The wealthier classes were constructing their own single storey homes on recently purchased building plots whereas the poor were attracted by the room rents which were lower than in Kumasi itself (Brook and Dávila, 2000).

3.4.2.4 Subriso

The village of Subriso in Tano district was located in the transitional forest savanna area on the northern border of the district on an unsealed road that linked the Kumasi Sunyani road and the important market town of Techiman. Although the area had once been a cocoa farming area deforestation, shortening of fallows and bush fires had led to increasing dominance of grasses on fallow land. A large variety of crops were grown for cash and consumption including tomato (*Lycopersicon esculentum*), maize, yam, cassava, groundnut, cocoyam, plantain, cowpea (*Vigna unguiculata)*, other vegetables, cocoa and oil palm. Cash crop production was aided by good links to Techiman, large urban markets such as Kumasi, and to neighbouring countries.

The population was the largest of the rural sites with around 3000 people. There were more settlers than native people, and these settlers included both long-settled people from nearby towns and villages of the Ashanti and Brong Ahafo regions, and more recent settlers from the north of the country. These settlers had been attracted by the availability of land for renting and sharecropping food crops after the demise of cocoa in the area. As at Gogoikrom, the land owning population included both the old settlers and the native population (Obiri-Darko *et al.*, 2000).

3.4.2.5 Yabraso

Yabraso was the driest site with noticeably different vegetation consisting of both patches of forest vegetation dominated by *Chromolaena odorata* and forest trees, and patches of guinea savanna vegetation with savanna trees and grasses. Cocoa had once been cultivated at Yabraso although none now remained. Dominant cropping patterns were yam based intercropping on grass dominated land and maize based intercropping on *Chromolaena odorata* dominated land. Farmers were also establishing teak (*Tectona grandis*) and cashew (*Anacardium occidentale*) plantations. Bush fires were a regular annual occurrence.

The village was located 19 km on an unsealed road from the district capital, Wenchi and had less than a thousand inhabitants. It was originally founded in 1921 and had strong economic, social and cultural links with the neighbouring larger settlement of Nsawkaw from where the native population had migrated to settle. There were more native people farming than settlers. The settler population was mostly from the north of Ghana and the village also received a large seasonal influx of northern migrant labour. Charcoal production was an important economic activity for the Sissala ethnic group from the Upper West region.

3.4.3 Crop production

Crop production is described in the following sections with particular reference to variation across field sites and to the influence of gender. Differences in the scale of crop production activities are outlined, first, for men and women, and then for land holding and non land holding farmers. Then land use, cropping patterns and livestock are described. This is followed by an account of land tenure, labour sources and finally market links for crop sales.

3.4.3.1 Scale and purpose of crop production

There were clear gender differences in the roles of men and women in crop production. Men focused on providing for the household's financial needs. They were said to 'concentrate on the economic value of what they were growing' and sold the majority of their produce. They grew cash crops such as cocoa and tomatoes or staple food commodities such as maize on a commercial scale.

Not all women had their own farm plots. Some women, particularly in peri-urban Kumasi, were not involved in farming at all, but concentrated on other income generating activities, particularly trading, and only went to farm when they needed to harvest their husbands' crops to prepare meals. Other women worked on their husbands' plots, but did not have farms of their own. In this and the following sections, quantitative data is presented for independent farming activities of individuals from the field sites. Fewer women than men are presented in the data as fewer women had their own plots. This appeared to be the case for native women as well as settler or non landholding women. Settler women are particularly disadvantaged with regards to crop cultivation as they do not have access to land without renting or share cropping, unlike native women who can inherit or be allocated land from their families, although men are usually given priority, particularly where land is scarce (Section 3.4.1.1; 3.4.3.3).

Table 3.8 to Table 3.11 show the area cultivated by male and female land holding and non land holding farmers at four of the field sites. As these are self-reported areas, they may

contain subjective errors that vary between and within sites. However, except for Gogoikrom, the figures do consistently show that women tended to cultivate smaller areas in their own right than men did. However these figures were only significant amongst native farmers at Yabraso and settler farmers at Subriso, despite a similar trend elsewhere. These figures also show that some women did cultivate as much land as men. Further research is recommended to understand the heterogeneity amongst the livelihoods of female farmers, their access to resources, and the conditions under which women are able to engage in income generating activities that rival those of men (Section 3.5.7). At Gogoikrom in particular, there are few women represented in the data and the female farmers surveyed may not be typical of female farmers in general. There were cases where cocoa farms had been inherited by Ghanaians living outside the village, and one woman was looking after a farm belonging to the family until it was divided up amongst the inheritors.

Table 3.8 Land area cultivated by male and female farmers at Oda

Total hectares self cultivated	**Proportion of farmers (%)**		**P**
	Men (n=17)	**Women (n=13)**	
<0.6 (First quartile)	17.6	30.8	0.684
0.6 – 3.0	41.2	61.5	0.269
> 3.0 (Third quartile)	41.2	7.7	0.101

Table 3.9 Land area cultivated by farmers at Gogoikrom

Total hectares self cultivated	**Proportion of land holding farmers (%)**		**P**	**Proportion of non land holding farmers (%)**		**P**
	Men (n=17)	**Women (n=6)**		**Men (n=34)**	**Women (n=10)**	
<1.4 (First quartile)	17.6	33.3	0.822	20.6	20.0	1.000
1.4 - 3.8	58.8	16.7	0.193	58.8	40.0	0.490
>3.8 (Third quartile)	23.5	50.0	0.487	20.6	40.0	0.406

Source: Obiri-Darko (2000)

Table 3.10 Land area cultivated by farmers at Subriso

Total hectares self cultivated	**Proportion of land holding farmers (%)**		**P**	**Proportion of non land holding farmers (%)**		**P**	
	Men (n=25)	**Women (n=13)**		**Men (n=21)**	**Women (n=11)**		
<1.4 (First quartile)	12.0	38.5	0.139	14.3	54.5	0.046	*
1.4 – 2.8	52.0	46.2	0.732	66.7	27.3	0.034	*
>2.8 (Third quartile)	36.0	15.4	0.341	19.0	18.2	1.000	

* $p \leq 0.05$ for differences between male and female farmers
Source: Obiri-Darko (2000)

Table 3.11 Land area cultivated by farmers at Yabraso

Total hectares self cultivated	Proportion of native farmers (%)		P		Proportion of settler farmers (%)	
	Men (n=27)	Women (n=29)			Men (n=17)	Women (n=3)
<1.0 (First quartile)	3.7	31.0	0.020	*	35.3	33.3
1.0 – 2.1	48.1	55.2	0.599		52.9	66.7
>2.1 (Third quartile)	48.1	13.8	0.005	**	11.8	0.0

* $p \leq 0.05$ for differences between male and female farmers
** $p \leq 0.01$ for differences between male and female farmers
Source: Obiri-Darko (2000)

The majority of women used most of their harvest and only sold what was surplus to their subsistence requirements. They sold small amounts of crops and used the income for day to day expenses for themselves and their families. Women's crop production activity, therefore, focused more on food needs, maintaining a continuous income for small purchases, and supplementing their husband's income, particularly during the lean season.

At Yabraso male farmers who were sharecropping or renting land for food crops cultivated significantly smaller areas than land holding male farmers (p=0.018 for farm areas within the lower quartile and p=0.013 for farm areas within the upper quartile) (Table 3.11). There was a similar trend at Subriso (Table 3.10) but the differences were not significant. At Gogoikrom the difference in cultivated area between land holding and non land holding farmers was less marked (Table 3.9). These differences between locations may be due to the longer standing and closer integration of settler farmers into the population at Subriso and Gogoikrom than at Yabraso. At Gogoikrom in particular, the use of sharecropping to establish cocoa farms resulted in the passage of land from native absentee landlords to settler farmers settlers (Section 3.4.3.3).

The area of land cultivated by individual farmers was greatest at Gogoikrom and Oda, and smallest at Yabraso. If these self reported areas are comparable, this may be related to the type of crop cultivated rather than land availability. The dominance of cocoa was common to Oda and Gogoikrom, and cocoa parcels were expanded each year when a farmer had land available. Furthermore, at Gogoikrom some farms that had been inherited had yet to be divided up amongst absent beneficiaries. At Yabraso, yam was the second most important crop (Table 3.12). The labour necessary for mounding, and the availability of planting material may have been constraints to the cultivation of larger yam plots, which therefore limited cultivated area at this site.

3.4.3.2 Land use

Three agricultural land use categories with broadly similar crop production potential were distinguished at all the field sites. These were the settlement area, upland to lowland suitable

for wet season cropping, and valley bottom areas where residual soil moisture enabled dry season cropping.

Livestock were kept in the vicinity of the settlement, and limited the potential for crop production in this area. A few scattered trees provided fruit and shade. Very small backyard farm plots were found, mostly in the peri-urban Kumasi villages on the edge of the built up settlement area.

Upland to lowland suitable for wet season cropping was by far the most extensive land type and existed at all the settlements. Fallow vegetation on this land is described in Section 4.2.1. At Oda and Yabraso this land was further divided into two according to crop production potential. At Oda a part of this upland was stool land that had been demarcated for the Oda-Kotoamso Community Agroforestry Project and on which collaborating farmers could cultivate half hectare plots with food crops under timber trees and optionally oil palm or kola (*Cola nitida*). At Yabraso upland to lowland was divided into forest land and guinea savanna woodland depending on the type of vegetation present (Section 4.2.1). Build up of organic matter was slower on savanna land due to the dominance of grasses on the fallow; ridging or mounding was required for cultivation and yam based intercropping prevailed. Forest land was predominantly used for maize based intercropping.

Lowland to valley bottom areas used for specialised cropping were either seasonally waterlogged, or else close to streams permitting irrigation in the dry season. Seasonally waterlogged areas were suitable for rice, taro (*Colocasia esculenta)* and sugar cane (*Saccharum officinarum*), and early maize using residual soil moisture. In the dry season they were used for vegetable crops. The extent of these lands varied between villages with relatively substantial areas at Gogoikrom and in some peri-urban villages, small areas at Subriso and very little at Oda and Yabraso.

Crops and cropping patterns

Despite broad similarities in land types across the five field sites, crops and cropping patterns were quite different due largely to differences in agro-ecology and market opportunities. Agricultural activities also differed according to gender, age, farmers' ethnic origin and land holding status. Similarities and differences in crops grown are outlined in the remainder of this section.

Differences and similarities between locations

Tree cropping, particularly cocoa, dominated land use at both Oda and Gogoikrom, although at Gogoikrom young cocoa plots dominated whereas at Oda there was more of a mixture of

mature and young plots (Table 3.12, Table 3.13, Table 3.14, Table 3.15). At both sites farmers were in the process of expanding the area of oil palm. At Gogoikrom rice was cultivated in valley bottoms. At Oda, farmers cultivated food crops and established trees crops including kola on land under the Oda-Kotoamso agroforestry project. At Oda the recent creation of a small-scale *gari*[10] processing unit and an assured market had recently increased the importance of cassava as a cash crop.

Table 3.12 Crop area as a percentage of total cultivated area at Gogoikrom, Subriso and Yabraso

Main crop[11]	**Crop area as percentage of total cultivated area**			
	Gogoikrom (73 farmers)	**Subriso (71 farmers)**	**Yabraso (76 farmers)**	**All three sites (221 farmers)**
Maize (*Zea mays*)	12.1	34.9	48.7	29.5
Cocoa (*Theobroma cacao*)	63.1	4.0	0.0	26.3
Plantain (*Musa paradisiacal*)	3.0	27.8	0.0	10.7
Yam (*Dioscorea spp.*)	0.2	5.2	29.3	9.5
Rice (*Orzya sativa*)	14.1	1.2	0.0	6.0
Oil palm (*Elaeis guineensis*)	6.4	8.8	0.6	5.8
Cassava (*Manihot esculenta*)	0.9	6.3	8.7	4.8
Groundnut (*Arachis hypogaea*)	0.0	3.2	4.2	2.2
Pepper (*Capsicum annuum*)	0.1	2.9	3.8	2.0
Tomato (*Lycopersicon esculentum*)	0.0	3.0	0.3	1.1
Teak (*Tectona grandis*) and cashew (*Anacardium occidentale*)	0.0	0.0	2.5	0.6
Citrus (*Citrus spp.*)	0.0	1.4	0.3	0.6
Other vegetables (garden egg (*Solanum spp.*), onion (*Allium cepa*), okra (*Abelmoschus esculentus*))	0.0	0.9	0.9	0.5
Cowpea (*Vigna unguiculata*)	0.0	0.5	0.6	0.3
Sugar cane (*Saccharum officinarum*)	0.1	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0

Source: Obiri-Darko (2000)

[10] *Gari* is made by drying, grating and fermenting pieces of cassava, and is a common foodstuff in Ghana

[11] Main crop refers to the dominant crop found on a farm, which is often intercropped or found in association with other things. These intercrops were not included in the calculations. The importance of cassava in particular, as the most common intercrop, is likely to be underestimated by these figures.

Table 3.13 Land use and cropping practices at Oda

Land use category	Form of agriculture	Purpose of production	Description
Settlement area	Livestock: poultry and sheep	Cash income from sales particularly as a form of security	Poultry: free range flocks of 1 – 100 birds Sheep: 1 – 10 animals penned and stall fed until 3p.m. after which they were allowed to roam
Oda-Kotoamso Community Agroforestry Project	Dispersed trees on cropland	Food production or cash income	Timber trees spaced at 10m x 10m intercropped with food crops. Kola or oil palm could also be grown.
All other upland to lowland	Mature tree crop plantations	Cash income	Fully yielding cocoa (>8 years), oil palm, citrus, rubber or coffee. Forest trees might also be present particularly on plantations with older more shade tolerant cocoa varieties.
	Young tree crop plantations		Young tree crops not yet yielding to their full potential: cocoa (4 – 7 years), oil palm or citrus. Forest trees might also be present to provide shade.
	Mixed food crop plots with the establishment of tree crops	Predominantly food production	Cocoa is established with plantain, cocoyam and cassava as shade crops with additional intercrops of vegetables and maize. Forest trees might also be retained in the initial years to provide shade. Food crops were harvested for up to three years. The same system was practiced for oil palm and citrus although the shade properties of intercrops were less important. Alternatively oil palm might be re-established on old sites as old trees were felled and tapped for palm wine and distilling *akpeteshie* (a local spirit).
	Mixed food crop plots	Predominantly food production	Plantain and cassava were the major crops with some additional intercrops which included maize, vegetables (pepper, garden egg, tomato and okra), cocoyam, yam, maize, cowpea or groundnut.
	Intercropped and sole cropped food crops	Predominantly cash income	Maize intercropped with cassava Major season maize followed by minor season cowpea Sole cassava, maize, rice or sugar cane. Mixtures or sole stands of pepper, garden egg, tomato and okra.

Table 3.14 Land use and cropping practices at Gogoikrom

Land use category	Form of agriculture	Purpose of production	Description
Settlement area	Livestock: poultry, sheep, goats and pigs	Cash income from sales particularly as a form of security. Food production	Poultry: free range flocks which include chicken, guinea fowl and ducks Sheep and goats: penned and stall fed during the day and allowed to roam at night. Also pigs.
Upland to lowland	Mature tree crop plantations	Cash income	Cocoa and oil palm. Forest trees might also be present to provide shade particularly on plantations with older more shade tolerant cocoa varieties.
	Young tree crop plantations	Future cash income	Young tree crops not yet yielding to their full potential: cocoa (4 – 7 years) and oil palm. Forest trees may also be present to provide shade.
	Mixed food crop plots with the establishment of tree crops	Predominantly food production and future cash income	Cocoa was established with plantain, cocoyam and cassava as shade crops with additional vegetable intercrops. Forest trees might also be retained in the initial years to provide shade. Food crops were harvested for up to three years. The same system was practiced for oil palm although the shade properties of intercrops were less important.
	Mixed food crop plots	Food production or cash income	Intercrop of plantain, cassava, maize, cocoyam and vegetables. Maize might be planted at close spacing in the first year.
Lowland to valley bottoms	Specialised valley bottom farming	Predominantly cash income	Sole rice or maize Rice intercropped with maize Vegetables (pepper, tomatoes, onion, shallots, garden egg) Oil palm – either being established amongst food crops or mature plantations

Source: Obiri-Darko *et al.*, 2000; Frost, 2000

Table 3.15 Field types at Gogoikrom

Field type	Proportion of farmers (%)				
	Natives		Settlers		Total (n=76)
	Men (n=6)	Women (n=5)	Men (n=49)	Women (n=16)	
Cocoa with food crops	83.3	100.0	83.7	87.5	85.5
Rice or rice/maize	0.0	0.0	34.7	25.0	27.6
Maize intercropped with other things	16.7	0.0	18.4	18.8	17.1
Mixed food crops	16.7	20.0	16.3	6.3	14.5
Sole maize	0.0	0.0	16.3	6.3	11.8
Oil palm with food crops	16.7	20.0	10.2	6.3	10.5
Sole cocoa	0.0	0.0	8.2	6.3	6.6
Oil palm	16.7	0.0	0.0	6.3	2.6

Source: Obiri-Darko (2000)

The dominant feature of cropping at Subriso was the diversity of crops grown and sold, the forest savanna transitional area being suitable for a wide range of crops. Maize based and plantain based intercropping dominated (Table 3.12, Table 3.16, Table 3.17). Vegetable cultivation, particularly tomato, was an important source of cash income.

Table 3.16 Land use and cropping practices at Subriso

Land use category	Form of agriculture	Purpose of production	Description
Settlement area	Livestock: poultry, sheep and goats	Cash income from sales particularly as a form of security. Food production	Poultry: free range flocks Sheep, goats: small flocks
Upland to lowland	Mixed cropping	Household consumption with some sales, especially plantain	Maize, plantain, cassava, cocoyam, yam, groundnut, vegetables (tomato, pepper, okra, garden egg, onion), oil palm. One crop sometimes dominated the others in the first year, particularly plantain, yam, groundnut or maize. Later on the plot might be dominated by plantain, cassava and cocoyam.
	Monocropping and intercropping	Predominantly cash sale	Maize, groundnuts, yam, wet season tomatoes and pepper were the main crops. A few farmers grew okra, garden egg, cowpea, onion or shallots. Cassava was often intercropped as the second crop.
	Tree crop plantations	Cash sale	Cocoa or oil palm: very few remained in the village
Lowland to valley bottoms	Monocropping	Cash sale	Dry season tomatoes or rice

Table 3.17 Field types at Subriso

Crop parcel	Proportion of farmers (%)				
	Natives		Settlers		All farmers (n=72)
	Men (n=14)	Women (n=7)	Men (n=34)	Women (n=17)	
Maize (sole, intercropped or mixed)	57.1	14.3	64.7	82.4	62.5
Plantain (usually mixed with other crops)	71.4	100.0	32.4	52.9	51.4
Yam (sole or intercropped)	28.6	28.6	29.4	41.2	31.9
Cassava (sole or intercropped)	28.6	42.9	20.6	41.2	29.2
Groundnut	7.1	28.6	14.7	29.4	18.1
Tree crops (citrus, cocoa, oil palm)	21.4	14.3	20.6	5.9	16.7
Pepper	35.7	14.3	14.7	29.4	22.2
Tomato	28.6	0.0	17.6	5.9	15.3
Other vegetables (garden egg, onion/shallot, okra)	14.3	14.3	2.9	11.8	8.3
Cowpea	0.0	0.0	0.0	11.8	2.8
Rice	0.0	0.0	5.9	0.0	2.8

Source: Obiri-Darko (2000)

At Yabraso the presence of both forest and savanna land, and the different crops cultivated on them was distinctive. Maize based cropping dominated on forest land and yam based cropping on savanna land (Table 3.12, Table 3.18, Table 3.19). Land holding farmers were attempting to establish tree crop plantations for cashew and teak.

Table 3.18 Land use and cropping practices at Yabraso

Land use category	Form of agriculture	Purpose of production	Description
Settlement area	Livestock: poultry, sheep and goats	Cash income from sales particularly as a form of security. Food production	Poultry: free range flocks Sheep, goats: small flocks Small ruminants were not penned but browsed in the vicinity of the settlement.
Forest land	Maize based monocropping and intercropping	Cash sale and household consumption	Maize might be intercropped with cassava, plantain, cocoyam, pepper, garden egg, tomato or oil palm.
	Vegetable monocropping or intercropping	Predominantly cash sale	Pepper was the most common vegetable. Others were garden egg, tomato, okra and onion. Cassava might be intercropped
	Cassava monocropping	Cash sale and household consumption	
Guinea savanna woodland	Yam based monocropping and intercropping	Cash sale and household consumption	Yam was grown on mounds. Intercrops were cassava, groundnut, pepper, okro, garden egg, tomato, cocoyam, maize, sorghum, upland rice, teak or cashew.
	Groundnut monocropping and intercropping	Cash sale and household consumption	Groundnut might be intercropped with cassava.
	Cassava monocropping	Cash sale and household consumption	
	Tree crop plantations	Cash sale	Teak or cashew

Table 3.19 Field types at Yabraso

Field type (i.e. main crop)	Proportion of farmers (%)				
	Natives		Settlers		All farmers (n=76)
	Men (n=27)	Women (n=29)	Men (n=17)	Women (n=3)	
Yam	92.6	82.8	64.7	100.0	82.9
Maize	92.6	69.0	88.2	66.7	81.6
Cassava	14.8	37.9	23.5	66.7	27.6
Vegetables (onion, tomato, pepper, garden egg)	7.4	48.3	11.8	0.0	26.3
Groundnut	0.0	44.8	0.0	0.0	17.1
Tree crops (teak, cashew, oil palm, citrus)	14.8	7.9	0.0	0.0	13.2
Cowpea	0.0	0.0	5.9	0.0	1.3

Source: Obiri-Darko, 2000

Land use in peri-urban Kumasi was in some ways quite different to that at the other field sites (Table 3.20). Unlike at the other rural forest and transition field sites plantain did not thrive in many villages due to low soil fertility and/or pest problems and was confined to backyard plots. The proximity of the urban snack market promoted the cultivation of taro, sugar cane and early maize in valley bottoms. Cassava was a more important cash crop than at Gogoikrom, Subriso and Yabraso possibly due to its ability to thrive on soils of low fertility, low management requirements and its bulkiness which could make proximity to Kumasi an

advantage. In comparison to the rural sites there were also differences in the vegetables grown commercially with exotics such as sweet pepper (*Capsicum annuum var. grossum*), lettuce (*Lactuca sativa*) and carrot (*Daucus carota*) being grown in addition to the more traditional okra, onion, pepper, tomato and garden egg. More intensive livestock production was also a feature of peri-urban Kumasi, but these enterprises were little integrated with food crop production.

Table 3.20: Land use and crops in peri-urban Kumasi

Land use category	Form of agriculture	Purpose of production	Description
Settlement area	Small-scale livestock: small numbers of poultry, pigs, sheep and goats.	Cash income from sales and food production.	Poultry: free range flocks of up to 100 Sheep, goats: small flocks (up to 10) which might be penned and stall-fed for part of the day. Pigs were penned.
	Occasional intensive poultry farms and larger herds of sheep or cattle.	Cash income	200 or more birds in a battery unit with road access but not within the settlement. Small herds of sheep or cattle were kraaled close to the settlement but grazed elsewhere on wasteland and fallow land. A Fulani man was often employed to take care of cattle.
	Backyard farm plots	Household consumption	Typically very small areas of plantain, banana, cassava and vegetables were grown next to the house.
Upland to lowland	Bush fallow mixed food crop farming	Household consumption with some sales.	Mixed cropping of maize, cassava, plantain, cocoyam and vegetables.
	Bush fallow monocropping and intercropping	Predominantly cash sale	Cassava maize intercrop or sole crops of cassava, yam or maize.
	Commercial vegetable cropping	Cash sale	Sole cropping of vegetables, rainfed on upland in the wet season and irrigated on the lower slopes in the dry season. Most commonly tomato and garden egg. Cabbage, cowpea, cucumber, okra, pepper, watermelon, beans, carrot and onion were also cultivated.
	Tree crop plantations	Cash sale	Cocoa, oil palm, citrus and teak
Lowland to valley bottoms	Specialised valley bottom farming	Cash sale	Sole cropping of taro, sugar cane, rice and maize grown for an early harvest on residual soil moisture

Differences and similarities influenced by land holding status and origin

In addition to differences in crops grown between field sites, there were also differences within sites between native and settler farmers, men and women, and young people and old people. Differences in land use between native and settler farmers appeared to stem from differences in land access as well as preferences for different crops. Rice and sugar cane, which are labour intensive crops, were grown predominantly by northern settlers at

Gogoikrom (Table 3.15) and in peri-urban Kumasi whereas southern native farmers grew taro, early maize or rented out valley bottom land to others.

At Subriso maize was a significantly more important crop for settler than for native farmers (Table 3.21), and at both Subriso and Yabraso maize sole cropping was significantly more important to settlers than natives (Table 3.21, Table 3.22). Tenancy arrangements for non land holding farmers limited their access to land to one or two years, preventing cultivation of intercrops. Where land was rented for a single year two maize crops might be grown to exploit its use as much as possible. Furthermore, farmers from the north sometimes returned home after only one season, and at Yabraso farmers may have focussed their intercropping on yam plots where tenancy periods appeared to be longer. Native farmers had more secure access to land for longer periods enabling more diverse cropping patterns. They cultivated significantly more plantain than settler farmers at Subriso (Table 3.21). At Yabraso, only native land holding farmers were permitted to cultivate tree crops.

Table 3.21 Maize and plantain cropping by native and settler farmers at Subriso

Field type	Number of farmers		P
	Natives (n=21)	Settlers (n=51)	
Maize sole cropped	3	22	0.019*
Maize intercropped or mixed	6	17	0.694
Maize (any)	9	36	0.027*
Plantain as the main crop	17	20	0.001***

* $p \leq 0.05$ for differences between native and settler farmers
*** $p \leq 0.001$ for differences between native and settler farmers
Source: Obiri-Darko (2000)

Table 3.22 Maize cropping by native and settler farmers at Yabraso

Field type	Number of farmers		P
	Natives (n=56)	Settlers (n=20)	
Maize sole cropped	29	16	0.028*
Maize intercropped or mixed	16	1	0.063
Maize (any)	45	17	0.901

* $p \leq 0.05$ for differences between native and settler farmers
Source: Obiri-Darko, 2000

Differences and similarities between men and women

Discussion with farmers and farm visits revealed that there were some differences in cropping by male and female farmers. In keeping with their role as earners of cash income men focused on high value or intensive cash crops, whereas women cultivated more of the staple food stuffs, were more likely to have a wider mixture of crops on their fields (for home consumption), and were more likely to sell low value bulky or less intensive cash crops. Plantain and cassava were more important sources of income for female farmers than for male farmers. Both are staple food stuffs and small quantities of both are available for most of the

year, although bulk sale of plantain is also a good source of income and was exploited by male as well as female farmers. Data from the structured interviews at Subriso and Yabraso presented in the following paragraphs supported these conclusions. At Gogoikrom differences between male and female farmers were less marked and may be a characteristic of a cocoa farming village dominated by settler farmers and absentee landlords where land is now inherited by individuals who did not originally reside in the village. Fewer female farmers at Oda than at Gogoikrom appeared to cultivate areas as large as those of men.

Maize was cultivated by the majority of farmers at Subriso and Yabraso (Table 3.17; Table 3.19), but male farmers cultivated significantly larger areas than female farmers (Table 3.23). Similarly, male farmers cultivated larger areas of yam than female farmers (Table 3.24).

Table 3.23 Mean maize area cultivated by male and female maize farmers at Subriso and Yabraso

Location	**Mean area cultivated**		**P+**
	Men	**Women**	
Subriso	4.0	2.0	0.008**
Yabraso	2.8	2.0	0.033*

+ independent samples T test
* $p \leq 0.05$
** $p \leq 0.01$
Source: Obiri-Darko, 2000

Table 3.24 Mean yam area cultivated by male and female yam farmers at Subriso and Yabraso

Location	**Mean area cultivated**		**P+**
	Men	**Women**	
Subriso	1.2	0.6	0.088
Yabraso	1.8	1.0	0.002**

+ independent samples T test
** $p \leq 0.01$
Source: Obiri-Darko, 2000

Female farmers at Subriso and Yabraso cultivated more of the low value crops groundnut and cassava than male farmers although the differences were not always significant (Table 3.25; Table 3.26). Planting and weeding of groundnut was done by women, even where farm income was not controlled by women. At Subriso husbands sometimes cleared plots and prepared mounds, before handing the plot over to their wives. Groundnut cultivated on moist sandy lowland soils was one of the first crops to be harvested and income from sales was important for food and other purchases before the main harvest, and for investing in the weeding of other fields.

Table 3.25 Gender differences in cassava and groundnut cropping at Subriso

Crop	Number of farmers cultivating crop		P
	Men (n=48)	Women (n=24)	
Groundnut as a main crop or intercrop	10	12	0.011*
Cassava as a main crop	11	10	0.099

* $p \leq 0.05$
Source: Obiri-Darko, 2000

Table 3.26 Gender differences in cassava and groundnut cropping at Yabraso

Crop	Number of farmers cultivating crop		P
	Men (n=44)	Women (n=32)	
Groundnut as a main crop or intercrop	0	13	0.000***
Cassava as a main crop	8	13	0.031*

*** $p \leq 0.001$
* $p \leq 0.05$
Source: Obiri-Darko, 2000

Women were significantly more likely to cultivate vegetable crops that did not require agro-chemicals such as onion and pepper than more resource intensive vegetables such as tomato and garden egg, whereas men cultivated all vegetables crops (Table 3.27).

Table 3.27 Gender differences in vegetable cultivation at Subriso and Yabraso

Crop	Number of farmers cultivating crop as a main crop		P
	Tomato, garden egg or cowpea	Pepper, onion or okra	
Men (n=92)	13	13	1.000
Women (n=56)	6	20	0.002**

** $p \leq 0.01$
Source: Obiri-Darko, 2000

Differences and similarities between farmers of different age groups

There appeared to be differences in the crops grown by young (male) farmers and older (male) farmers. Cowpea and vegetables appeared to be more important to young people (at Subriso and Oda) whereas older farmers were more likely to focus on cash crops such as maize at Subriso or additional tree crops at Oda. Younger farmers may have preferred to cultivate crops that brought quick returns (sometimes in order to move out of farming) and were able to invest a lot of their own labour, whereas older people had greater access to land and so expanded their plots rather than investing in risky resource intensive short term crops. At some locations, such as at Oda, younger farmers may have preferred to expand their tree crop farms but were unable to do so due to land shortages. Despite these considerations, differences between the different age groups were not apparent for the data presented in Table 3.17, possibly due to the low number of young people represented in the sample (only one fifth of the sample was less than 35 years old).

Livestock production

Small-scale livestock production took place at all the field sites and commonly involved poultry, sheep and goats, although in some settlements goats were banned to prevent crop damage when livestock were permitted to roam unattended. Around half of smallholder farmers at the study sites kept livestock. Poultry were kept on a free range basis and farmers had flocks of up to 50 birds. Sheep and goats were kept in small flocks of up to ten animals. In some settlements they were left to roam and find their own fodder. In other settlements they were penned and stall fed for part of the day to prevent them wandering onto farms and destroying crops. Farmers used livestock as a form of insurance in order to be able to obtain cash quickly, to generate additional income to invest in farming and other activities and for use in rituals.

In addition to small scale livestock production, larger more intensive commercial production took place at the peri-urban study site. This included intensive poultry units with a minimum of 200 birds, larger flocks of sheep and goats, flocks of cattle and pigs kept in pens. Men were generally the ones to invest in this type of livestock production (NRI, 1999). Northerners invested more in cattle, whereas Ashantis invested more in poultry and pigs. All ethnic groups kept sheep and goats (Table 3.28). Enterprises with the highest capital requirements i.e. poultry and cattle, were practised by older men whereas the age distribution of other enterprises was more equal. Enterprises with the highest capital requirements were also practised by men who were not crop farmers, but combined commercial livestock production with another profession (NRI, 1999).

Table 3.28 Choice of livestock enterprise by capital requirements of enterprise and ethnic origin of producers in the Kumasi Metropolitan Area

Farmer origin	**Capital requirements**	
	High	**Low**
Northerners	Cattle	
Ashantis and other southern ethnic groups	Poultry	Pigs
All ethnic groups		Sheep and goats

Source: adapted from NRI (1999)

There was limited crop-livestock interaction at all study sites. Crop and livestock farming were seen as separate activities, and were often practised by different people. The most common interaction was the feeding of cassava peelings to sheep, goats and pigs. Some vegetable farmers used poultry manure to supplement use of inorganic fertiliser but use of manure from other animals was rarer. Intensive poultry farmers used maize feed, but this was generally purchased in Kumasi.

3.4.3.3 Access to land

Land for farming was commonly obtained through inheritance, sharecropping and rental, although a variety of other means of acquisition were also possible. These are explained in Table 3.29. As elsewhere in Ghana, farmers used 'all their connections including those of birth, lineage, marriage, friendship and the market, to gain access to land from the land-holding families, and also from neighbouring stools' (Okali and Sumberg, 1999). Patterns of access to land varied at the field sites according to crops grown, patterns of in and out migration, and land scarcity.

Table 3.29 Forms of land acquisition

Means of land acquisition	Crops grown	Description
Clearing of virgin or otherwise unclaimed forest	Any	Clearing of virgin or otherwise unclaimed forest was the traditional means of establishing user rights. There was no longer any unclaimed forest left at any of the field sites.
Family land and inheritance	Any	Land was matrilineally inherited i.e. it passed from uncle to nephew, and from mother to daughter. The family also acted as a corporate body and the head, the *abusua panin*, gave out land to family members who required it. Inherited land had more secure user rights than allocated family land.
Gift	Any	Gifts were used to avoid the matrilineal inheritance system and pass land to offspring and wives. The passing had to be witnessed and the recipient of the gift offered *aseda*[12] to the giver before the gift was permanently recognised (if this was not done the matrilineal family could contest ownership on the death of the man).
Sharecropping: tree crops, *abunu* (halves)	Cocoa and other tree crops	A tree crop plot was established by the tenant. When it reached maturity it was divided in two. The tenant kept his half as long as the trees were on the land. The other portion was returned to the land owner. An initial fee (*aseda*) was paid to the landlord to witness the agreement, which where land was scarce such as at Oda, could be equivalent to the price of the land itself. The tenant provided all inputs and labour to establish the tree crop and kept all food crops, but shared early harvests of the tree crop.
Sharecropping: food crops *abusa* (thirds) and *abunu* (halves)	Food crops e.g. maize, cassava, plantain	The tenant farmer established the plot providing all the inputs. Maize was commonly on the *abusa* basis (i.e. one third of the harvest was given to the landlord). Plantain and cassava could be *abusa* or *abunu* (i.e. equal shares). Where crops were not harvested all at once the plot was split into two at maturity and each harvested from his own portion.
Purchase/lease	Any, commonly cocoa	Land purchase took the form of a lease of indefinite length. Drinks money equivalent to the value of the land was paid to the chief and the transfer was documented.
Rental	Short term cash crops e.g. tomato and maize	Rental might be for periods as short as 3 months or as long as 7 years. 1 or 2 years was common. Rental was paid in cash.
Spouse	Food crops	Where women had no other means of access to land, they could obtain it from their husbands, particularly in the case of settler farmers. Settler men might also marry native women and obtain land through their wife's family.
Stool land	Food crops	Rental for the land was paid to the stool, commonly after the harvest of the crops, and might be in cash or in kind. Not all stools had land for loan. Land that did exist might not previously have been considered suitable for cultivation (e.g. land unsuitable for cocoa at Oda, grassland at Yabraso, valley bottom areas now coming into rice production in peri-urban Kumasi).

[12] *Lit.* thanks. Often termed drinks or drinks money but usually given in the form of cash.

Table 3.29 continued

Means of land acquisition	Crops grown	Description
Other	Food crops	Land might be obtained on the basis of friendship or social ties with another person without any fixed means of payment. The tenant might give some of the harvest to the landlord. The crops grown depended on the arrangement. Stool land was sometimes reserved for members of the royal family. A type of taungya arrangement whereby the tenant farmer cultivates food crops at the same time as taking care of tree crops for the landlord (such as cocoa at Oda or teak or cashew at Yabraso). At Subriso a tenant sometimes cultivated tomato, and intercropped with cassava, which was shared with the landlord. Land for the cultivation of food crops might be provided to caretaker farmers by their employers. Cultivation of unused government (e.g. school) land with no arrangement. Temporary use of unused building plots (peri-urban Kumasi)

Land access by farmers from native and long-term settled families

The means by which native and settler farmers obtained land differed. The majority of native people cultivated their own land i.e. land for which they had long term user rights and did not make any payment (Table 3.30, Table 3.31, Table 3.32, Table 3.33). This was mostly allocated family land, inherited land, land belonging to another family member (such as a spouse or parent) or land gifted by another family member (such as a husband or father). Some native farmers also rented or sharecropped where they did not have sufficient land of their own, or where they did not have suitable land for their purposes, e.g. land next to a stream for cultivation of dry season tomato.

At Gogoikrom and Subriso the population included a substantial proportion of settlers whose families had been resident for a long time and had acquired land which was then passed through the family (Section 3.4.2.2, Section 3.4.2.4). The pattern of land acquisition for these settlers was therefore similar to that of the indigenous population (Table 3.31 and Table 3.32).

Table 3.30 Means of land acquisition for native farmers at Oda

Means of acquisition	Proportion of farmers (%) (n=37)
Matrilineal family	67.6
Father	45.9
The Oda Kotoamso Community Agroforestry Project	24.3
Other	13.5
Gift from husband	10.8
Land purchase	10.8
Sharecropping	10.8
Clearing of virgin or unclaimed land	5.4

Table 3.31 Land access by farmers at Gogoikrom

Land access	Proportion of farmers (%)							P
	Natives		Settlers				Total (n=72)	
			Ashantis		non-Ashantis			
	Men (n=5)	Women (n=5)	Men (n=13)	Women (n=9)	Men (n=35)	Women (n=5)		
Own land	80.0	80.0	69.2	33.3	14.3	0.0	34.7	0.000 ***
Sharecropping	40.0	40.0	30.8	66.7	77.1	100.0	63.9	
Caretaking	0.0	20.0	7.7	0.0	14.3	0.0	9.7	
Renting	0.0	0.0	0.0	0.0	17.1	0.0	8.3	
Free tenancy	0.0	0.0	15.4	11.1	14.3	20.0	12.5	

$p \leq 0.001$ for differences between native or Ashanti settlers (combined) and non-Ashanti settlers
Source: Obiri-Darko (2000)

Table 3.32 Land access by farmers at Subriso

Land access	Proportion of farmers (%)							P	
	Natives		Settlers				Total (n=71)		
			Brong Ahafo and Ashanti regions		Other regions				
	Men (n=13)	Women (n=8)	Men (n=15)	Women (n=6)	Men (n=18)	Women (n=11)			
Own land	92.3	87.5	80.0	100.0	5.6	0.0	53.5	0.000	***
Sharecropping	0.0	12.5	26.7	0.0	83.3	90.9	43.7		
Land rental	7.7	37.5	6.7	0.0	33.3	9.1	16.9		
Free tenancy	0.0	0.0	6.7	0.0	0.0	9.1	1.4		

$p \leq 0.001$ for differences between native or Brong Ahafo and Ashanti settlers (combined) and other settlers

Source: Obiri-Darko (2000)

Table 3.33 Land access by farmers at Yabraso

Access to land	Proportion of farmers (%)					P	
	Natives		Settlers		All farmers (n=75)		
	Men (n=27)	Women (n=29)	Men (n=16)	Women (n=3)			
Own land	100.0	93.1	6.3	0.0	73.3	0.000	***
Sharecropping	0.0	0.0	25.0	33.3	6.7		
Rental	0.0	6.9	56.3	66.7	17.3		
Free tenancy	0.0	0.0	25.0	33.3	6.7		

$p \leq 0.001$ for differences between native and settler farmers

Source: Obiri-Darko (2000)

Land access by settler farmers: sharecropping and renting

The most important means of land acquisition for more recent settler farmers was sharecropping and rental, with a few farmers using a free tenancy, i.e. land that they had acquired access to for free, but that was not their own, and a very small number of farmers had their own land (Table 3.31, Table 3.32, Table 3.33). At Gogoikrom some settlers acted as caretakers on mature cocoa farms for absentee landlords who might only visit their tenant farmers once a year when the income from the cocoa harvest was received. Many cocoa plots were inherited by people who did not originally establish them and did not reside in the village.

Land rental and sharecropping were generally seen as arrangements which were beneficial to both landlord and tenant – one supplying the land and the other the labour. Landlords saw sharecropping and rental as a means of obtaining an additional source of income from land that they could not farm themselves due to old age, illness, absence or lack of labour. Able-bodied farmers with a surplus of land might include those who had few resident relatives due to out migration of much of their family. Land was also rented out by farmers in urgent need of cash in the case of eventualities such as hospital fees or funeral expenses.

Sharecropping for tree crops, sharecropping for food crops and land rental all had their advantages and disadvantages for the tenant farmer (Table 3.34). Sharecropping tree crops enabled the landless to obtain tree crops but the initial fee for use of the land was very high, and where land was scarce could be equivalent to the value of the land itself. Cultivating tree crops strengthened a farmer's land use rights, more than any other form of tenure. When renting or sharecropping food crops tenant farmers were constantly aware that they could be dismissed by the landlord.

Table 3.34Advantages and disadvantages to the tenant farmer of different forms of land acquisition

Means of land acquisition	Advantages	Disadvantages
Sharecropping tree crops	- means for the landless to obtain tree crops - acquisition of a long-term asset which can be passed to others	- large initial fee for use of the land
Sharecropping food crops	- less risky than renting in the event of crop failure - landlords more likely to give out better quality land than for rental	- more interference from the landlord than with renting - risky when cultivating perennials - landlord decides when to harvest - higher cost for land use than for renting
Land rental	- less interference from the landlord than with sharecropping - lower cost for land use than sharecropping	- short tenancy periods preventing cultivation of perennials - more risky than sharecropping in the event of crop failure

The cost of land rental was not fixed but was determined by the crop to be grown, the area of land, the rental period, the productive potential of the land, the personal relationship between the landlord and tenant, the personality of the landlord and the current cash needs of the landlord (Table 3.35). Land rental appeared to be a cheaper means of obtaining land for cultivating food crops than sharecropping, but was considered more risky, as in the event of a crop failure cash payment for the land would still be necessary. Farmers could not cultivate perennial crops due to the short tenancy periods which were frequently only one or two years. When sharecropping food crops, landlords interfered more than with land rental, and tenants could not harvest crops until the landlord made the decision to harvest or share the farm. Although perennial crops could be cultivated farmers sometimes feared that the landlord would pick an argument with them before the plot was shared and dismiss them, taking the whole plot for themselves. However land given out for sharecropping may have been of better quality than land rented as the landlord would gain from cultivation of better quality land.

Table 3.35 Cost of land rental at Subriso

Farmer id.	Gender	Farmer origin	Crops grown	Parcel size (acres)	Cost of land rental (cedis*)
25	Male	Native	Groundnut	0.25	20 000 for 6 months
8	Male	Native	Groundnut with some maize	0.5	15 000 for 1 cropping season
4	Female	Settler	One or two crops of maize	1	60 000 for 1 year
23	Male	Settler	Two crops of maize followed by a years fallow and then a final maize crop	1	200 000 for 4 years
33	Male	Settler	Maize	4	50 000 for one year
33	Male	Settler	Maize	15	150 000 for one year
6	Male	Settler	Mostly maize, with yam, cassava and pepper on separate portions.	7.5	120 000 a year
23	Male	Settler	Pepper	0.25	100 000 for 2 years
14	Female	Native	Wet season tomato intercropped with cassava and some cocoyam	0.5	30 000 for 2 years
24	Male	Native	Wet season tomato intercropped with cassava and followed by maize	2	100 000 for 3 years
28	Male	Native	Wet season tomato intercropped with cassava on a sharecropping basis	3	60 000 for 3 months

*£1 ≈ 8,500 cedis

Overall, renting and sharecropping were less profitable means of farming than use of a farmer's own land. Payment for the land detracted from the profitability of the crop. Furthermore, where tenants were given lower quality land, it might be less productive due to lower fertility. Such land might also have a higher prevalence of weeds that were difficult to control than on higher quality land. These weeds could increase the labour required for land preparation and weeding.

The pattern of renting and sharecropping differed according to the crops that were grown. Sharecropping was common at Gogoikrom due to the dominance of cocoa and was used by absentee landlords to establish tree plots. Elsewhere, land for highly commercialised crops requiring high levels of input use such as tomato was usually rented. Land for other food crops such as maize was either rented or sharecropped. Sharecropping was more common at Subriso, whereas rental was more common at Yabraso, particularly for yam grown on savanna land. This may have been because income from sharecropping favoured the landlord more than rental and was therefore used more when land was scarce.

Land scarcity between locations

Land scarcity differed at the different study sites, for different types of land, and for different social groups.

Population density appeared to be lowest at Yabraso and the proportion of native people using sharecropping, rental, purchase or other means to acquire land was also lowest (Table 3.36). This might be some indicator of land scarcity, although there was also a lack of specialised cropping requiring valley bottom or similarly scarce land at this location.

Table 3.36 Land access by native and Ashanti and Brong Ahafo settler farmers at Gogoikrom, Subriso and Yabraso

Location	**Proportion of farmers using land other than their own (%)**
Gogoikrom (n=32)	46.9
Subriso (n=42	23.8
Yabraso (n=56)	3.6

P values from Chi square comparison

Location	Subriso	Yabraso
Gogoikrom	0.038*	0.000***
Subriso	-	0.002**

* $p \leq 0.05$
** $p \leq 0.01$
*** $p \leq 0.001$
Source: Obiri-Darko, 2000

Land scarcity appeared to be highest in peri-urban Kumasi. With the growth of Kumasi, land was being sold off in outlying villages, primarily for residential development (Brook and Dávila, 2000). This was a process that farmers had very little control over. Layout plans for residential areas were prepared by the regional town and country planning office. In most settlements allocation of plots was the ultimate responsibility of the chief. Proceeds from land purchases were termed 'drinks money' and equivalent to the market capital value of the land. Distribution of the proceeds was generally opaque but accrued to the chiefs, queenmothers and the Golden Stool (Asantehene). In the majority of villages, no compensation was given to families for farmland lost in this way, although compensation for standing crops might be given, and a share of the building plots (as little as one) might be allocated to the original landowners. The last land to be sold off was the wetland areas unsuitable for development (Blake *et al.*, 1997). Land tenure for family land was therefore less secure in peri-urban Kumasi than in the rural areas and land scarcity was a problem.

At Oda, situated in the apparently sparsely populated Western region, there was a scarcity of land suitable for cocoa. The area had been settled for over a hundred years and the population had therefore increased. Additionally, land was, in the past, permanently alienated from the indigenous people through sale, lease and sharecropping to settler farmers who came mainly from the Brong Ahafo region. The perennial nature of tree crops, the ability of farmers to expand their plots every year, and the use of herbicide which had enabled farmers to cultivate larger areas were all additionally said to contribute to land shortages. Nevertheless, there was

no shortage of suitable land available for food crop cultivation for farmers willing to cooperate with the Oda-Kotoamso Community Agroforestry Project.

At both Subriso and Yabraso it was not difficult for settler farmers to get access to land through sharecropping and rental if a farmer knew whom to ask. Nevertheless, settler farmers said they had problems gaining access to fertile land. At Subriso the land closest to the settlement was in higher demand and had been used intensively for crops such as tomatoes (which require ridging which disturbs the root stock in the soil from which the fallow will regenerate). Farmers said they might need to walk some distance from the settlement to find land with a longer fallow. Similarly at Yabraso, native farmers preferred to use forest land themselves and give out savanna land for sharecropping and rental.

Differences in land scarcity within the community

Land scarcity affected different social groups within the community at each of the study sites. At Oda land shortages for cocoa were felt more by the younger people, who claimed they were only given marginal land from the matrilineal family. This land had sometimes only had a short fallow, was seasonally waterlogged with many grass weeds or far from the settlement. Many young people had obtained land from the Oda-Kotoamso Community Agroforestry Project for food crops, and use of the project's land frequently appeared to indicate land scarcity (Moss 2001b). Native people had established cocoa plots on neighbouring stools where land purchase was actually less expensive than sharecropping at Oda. However the money required for sharecropping or purchase was difficult for young people to raise.

Women were also in a less favourable position with regard to land acquisition. In peri-urban Kumasi, women unable to move to other occupations and who continued to cultivate mixed food crops in upland areas were particularly vulnerable to having their land taken from them for development and being left without any means of providing for themselves. This was more of a problem for older women as younger women moved out of farming much more rapidly (Blake *et al.*, 1997). In the rural areas fewer women had farm plots in their own right than men. For most categories of Table 3.31 to Table 3.33 women were in a less favourable position than men in the same category, although these differences were not significant, probably due to the small sample size and also because direct comparisons are difficult to make. Men are more likely than women to rent or sharecrop land for specialised farming such as tomatoes or rice. At Oda women said they would establish cocoa plots if they had the land to do so, which was clearly not always the case as married men were more likely to be allocated land than women. At Subriso, female farmers preferred to farm close to the

settlement due to childcare demands and the preparation of meals, but this was the land in greatest demand by tomato farmers and had been most intensively used.

Settler farmers at Subriso and Yabraso sharecropping and renting found it difficult to gain access to fertile land as land owners preferred to farm the higher quality land themselves. Therefore these farmers were also more adversely affected by land scarcity than farmers who owned land.

3.4.3.4 Farm labour

Table 3.37 describes the different sources of labour for agricultural activities and the tasks they were associated with. The main source was the farmer with or without a spouse. Children also helped on the farm although their contribution was now less than in the past as school enrolment has increased and is around 80% (World Bank, 2003). The extended family appeared to only make a very small contribution to labour requirements, and was associated more with harvesting and processing activities.

Table 3.37 Sources of labour for agricultural activities

Source	Description	Activities performed
Household labour	Farmer, spouse, children and other household dependants	All activities.
The extended family and friends	Other family members and friends	Planting, harvesting, carting produce and processing e.g. dehusking and shelling maize and breaking cocoa pods
Daily wage labour (*by day*)	A days work involved about 5 hours. A standard rate existed, but with some variation. Food might also be provided.	Clearing, tree felling, stumping, weeding, mounding, ridging and earthing up
Contract labour	A specified sum of money was agreed for a defined amount of work.	Commonly clearing and tree felling
Communal exchange labour (*nnoboa*)	A group of farmers helped each other on their farms in turn. The farmer receiving the labour provided food and drinks.	Burning, planting and harvesting
Caretaking	Caretaking occurred on mature cocoa farms. The caretaker farmer (who was usually male) and his family provided all the labour and the landlord provided all the inputs. At harvest the caretaker received one third of the revenue from the crop as payment.	All activities on mature cocoa farms.
Annual labourers	Annual labourers were paid in cash and might also receive accommodation.	All activities.
Provision of labour in exchange for accommodation	Migrant farmers from the north might pay room rent by providing labour on their landlord's farm (Obiri-Darko, 2003 pers. comm.). In peri-urban Kumasi the same was true of commuters and labourers (Blake *et al.*, 1997).	Any

Farmers commonly supplemented their own and family labour with hired labour, although the use of hired labour varied amongst different social groups and was more common amongst highly commercially orientated farmers, older farmers and female farmers. Various forms of paid labour existed (Table 3.37), and were used predominantly during land preparation and weeding. These were the most physically demanding and/or most labour intensive tasks. Daily wage labour was the most frequently used form of wage labour. Some farmers preferred contract labour as they thought they could ensure a higher standard of work, particularly for clearing and weeding. If land was not weeded properly, weeds would resprout sooner, and require weeding a second time. Caretaking was only common at Gogoikrom and associated with the absent cocoa farm owners at the site. Annual labourers were only used by the largest of smallholder farmers (only one instance was found in this study – at Oda) and by large-scale plantation owners (again at Oda). Hired labour was mostly provided by migrant labourers and settlers from the north at the Gogoikrom, Subriso and Yabraso field sites, by the young native people of the community at Oda and by both in peri-urban Kumasi.

Table 3.38 shows the cost of daily wage labour for land preparation and weeding at Subriso in August 2000. Women were frequently paid 1 000 cedis or about 20% less than men for the same task. Most wage labour was done by men but planting and weeding groundnut were tasks for which women were specifically employed. Estimates of labour and cash expenditure for tasks such as clearing and weeding varied considerably depending on the vegetation (although differences in farmers' estimates of area may also have contributed to the variation).

Table 3.38 Cost of daily wage labour for land preparation and weeding at Subriso during August 2000.

Task	Cost per day*	Cost per acre (cedis)
Clearing	5 000	33 000 – 60 000 or more depending on the vegetation
Making yam mounds	5 500 (per 100 mounds)	110 000 (@ 2000 mounds per acre)
Making groundnut mounds	5 000 (per 100 mounds)	60 000 (@ 1200 mounds per acre)
Ridging and earthing up tomato	5 500 (per 100 ridges)	22 000 (@ 400 ridges per acre)
Weeding	5 000	25 000 – 60 000 or more depending on the nature and quantity of weeds
Weeding groundnut (women)	3 500	42 000 – 105 000 or more depending on the nature and quantity of weeds

* All figures include meals - if lunch is added 500 cedis is deducted. All figures are for male labour except for groundnut. £1 ≈ 8,500 cedis
Source: four group interviews and 29 individual interviews at Subriso in August 2000

Some farmers belonged to communal labour exchange groups (*nnoboa*). These were mostly northern settlers and young people. Other farmers obtained labour in exchange for providing accommodation to migrant farmers at Subriso (Obiri-Darko, 2003 pers. comm.), and labourers and commuters in peri-urban Kumasi (Blake *et al.*, 1997).

The gender division of labour

There was a clear gender division of labour on the farm (Table 3.39). Clearing a plot is traditionally a male role and is associated with making a claim to land. Other physically demanding aspects of land preparation including mounding and ridging, and the application of agrochemicals were also almost exclusively done by men. Women did more of the planting, harvesting, carrying and processing activities. Both men and women did weeding. Where both cocoa and food crops were grown such as at Oda, men spent more time on land clearing and preparation, and tended mature cocoa plots, whereas women spent more time on young plots planting and maintaining food crops.

Table 3.39 Gender division of labour on farm

Activity	Men	Women
Land preparation: clearing, tree felling and stumping, burning, ridging and mounding	•	
Planting		•
Weeding	•	•
Harvesting		•
Application of agrochemicals	•	
Transportation of farm produce to the house		•
Processing		•

The seasonality of labour supply and demand

Labour demand was generally highest after the arrival of the rains and throughout the major rainy season from February to July, although there were differences between sites due to differences in the nature of the fallow vegetation and cropping calendar which influenced the timing of land preparation. The supply of labour from migrant labourers was only available for part of the year as many migrants returned home for the farming season in the north from March onwards. However ability to pay for hired labour appeared to be more of a constraint than actual availability of labourers, particularly for weed management.

Weeds, and in particular the invasion of *Chromolaena odorata* (*acheampong*) and grasses, especially *Panicum maximum,* had become much more of a problem since the decline of cocoa farming and the reduction in tree cover. With shorter fallows weed seeds and root stock were no longer eliminated in the fallow period. Furthermore, hired labour was considered expensive and the period of greatest labour demand for weeding coincided with the period of least cash and food availability in the community and the peak period for obtaining loans. Many farmers were unable to hire labour for weeding and access to labour was connected to cash flow.

Labour sources used by farmers with different social characteristics

Patterns of access to and use of labour differed amongst different social groups. Female household heads were often assisted by their children, or in the case of women with absent husbands, by their husbands. This help would take the form of actual assistance on the farm from children and husbands near at hand or else financial assistance for hiring labour. Older women were obviously in a better position to receive assistance from adult offspring than younger women. Some women were also assisted by female friends.

Wives also used hired labour and were helped on their farms by their children. They also received some help from their husbands although there were clearly differences in the relations between husband and wives with regard to the degree of independence of their farming activities (Appendix II). Some women maintained strict separation of their own farming activities and had to repay any money borrowed from their husbands for hiring labour. Others created a plot themselves, providing all inputs and paying for hired labour but then handed over any proceeds from farm sales to their husbands. Other wives might be helped on their farms by their husbands or given financial assistance. It is possible that where these wives then retained control of the income from these farms, they were the wives of men who were already themselves successful or wealthy farmers and therefore able to be generous.

For women, the gender division of labour made them more dependent on others and on hired labour for land preparation and spraying agro-chemicals than men, who were able to carry out all farm tasks themselves. Furthermore, the traditional role of women in carrying out domestic tasks, pregnancy, child birth, care of the husband, children, the sick and the elderly all had a large opportunity cost on women's time. Women also generally had more limited access to capital to hire labour and to the labour of other family members. Labour constraints might therefore be expected to affect women more than men, and may be an additional reason for their more limited independent farming activities. During a farm problem ranking exercise at Oda women ranked weeds as a problem more highly than either of two male groups. Their busiest time was also different to that of men and coincided with the peak weeding time.

Unlike women, men could provide all the labour on the farm themselves. Their reliance on hired labour varied according to their access to cash, crops grown and area cultivated. Where production was on a larger scale, intensive or cash orientated, men tended to hire more labour. Men also received labour on their farms from their spouses, which varied according to the other demands on their wife's time. However men generally received more labour from their wives than they provided in return. Wives frequently assisted their husbands at the rural locations in planting, weeding and harvesting. Where men had a number of different plots,

they sometimes handed over responsibility for one or two of them to their wives, particularly groundnut plots or mixed food crop plots. However, in peri-urban Kumasi competition for labour between agricultural and non-agricultural activities reduced the amount of family labour available. Women were more likely to have another occupation, usually trading, and might therefore only visit their husband's plot to collect firewood and bring food stuffs to the house.

Younger men appeared to be the least dependent on hired labour, due to their greater physical strength than women and older men, and their lack of cash. They would hire labour for specialised commercial cropping with intensive labour demands such as tomatoes, but for other crops, might provide all farm labour themselves. Young men were more likely to have wives in their child bearing years, or in peri-urban Kumasi, wives with their own trading or food processing businesses who only went to farm to harvest food stuffs. Their children were also likely to be babies or in school so that family labour was limited. Furthermore, young men were also less able to call upon the extended family than older men, although before marriage their mothers and siblings might help them on the farm.

3.4.3.5 Marketing

Cocoa was sold from September to December to cocoa buying companies which had warehouses located in the cocoa producing villages. The farm gate price was fixed by the government every year making it a relatively stable income source in comparison with the sale of food crops.

The majority of food crops were sold to farm gate traders coming from markets in all the different regions of Ghana, and sometimes from neighbouring countries. Subriso and Yabraso were located on relatively busy rural roads and villages in peri-urban Kumasi were close to a large urban market. These locations therefore had the best market links. Farm gate sales were also important for marketing food crops at Gogoikrom and Asankrangua, but these villages were at the end of roads, and were less frequented by farm gate traders than the other locations. Farmers claimed that farm gate prices compared well with market prices once transportation and other marketing costs were taken into account.

Where farm gate traders did not come to the village, and when farmers only had small quantities of crops for sale, farmers sold their crops within the village or took them to market themselves. Individuals marketed their own crops where these were cocoa, or other large sources of income, such as maize and tomato at Subriso. Women marketed crops with sales of

a lower value, providing an account of the transaction to their husbands where it was his crops that were sold.

Marketing was a key factor in determining returns from farming. The seasonality of crop production resulted in large fluctuations in the price of the major food commodities including maize, yam, plantain, cassava and groundnut. Prices for food crops were generally low during the harvest season from August to December, and then gradually rose in the following year until the next harvest. Prices of major commodities such as maize could vary by as much as a factor of five or more from harvest to the time of peak prices the following year. Farmers had to store their crops and sell later, harvest early, or else produce out of season to obtain higher returns from farming. Women also processed cassava, maize and oil palm to increase income from sales. The price of perishable vegetable crops, notably tomato, was even more unstable and varied from week to week. As the crop was capital intensive in terms of labour and agro-chemical inputs, farmers could, largely by chance, make either a loss or a substantial profit.

Farmers felt they had little bargaining power with farm gate traders. The traders had better communications with the major markets and farmers felt that they 'dictated' crop prices. This was especially so when the market was flooded, so that traders could buy elsewhere. Fewer traders came to the villages forcing farmers to accept the price they were offered at these times. Farmers accepted these prices due to the urgency of their cash requirements following the lean season.

3.4.3.6 Sources of income

Farmers frequently had more than one source of income. The sale of crops was the main source of income for farmers at the four rural locations whereas in peri-urban Kumasi many farmers combined crop production with off-farm employment.

Crop sales

Cash crops varied with location. Cocoa was the most important crop at Oda and Gogoikrom, whereas maize, cassava, rice and vegetables were the most important in peri-urban Kumasi; maize, tomato and plantain at Subriso and yam, maize, cassava, groundnut and pepper at Yabraso.

Farmers attempted to provide for cash needs throughout the year through crop storage and the cultivation of multiple crops for sale. Both food and cash was scarce during the main rains from April to June for farmers across the field sites, particularly for farmers without off-farm sources of income. At Subriso groundnut was one of the earliest crops to be harvested and income could be reinvested in weeding other crop parcels. Similarly in peri-urban Kumasi,

Gogoikrom and Yabraso maize was grown on lowland moisture retentive soil and harvested early. Cocoyam, plantain and cassava were all available in small quantities throughout the year for food needs and cash sale. At the cocoa locations the sale of food crops was used as an extra source of income from August to October prior to the main period of cocoa harvest and sale.

Other income sources

Farmers had a range of income sources in addition to crop farming. In peri-urban Kumasi the greater employment opportunities offered by the proximity to Kumasi and the insecure future of farming in the face of urban development on agricultural land resulted in many farmers combining off-farm employment with crop production (Blake *et al.*, 1997). In the rural locations less than fifty percent of farmers had off-farm employment and many of these were activities carried out on a part time basis and only practised intermittently. The income sources in peri-urban Kumasi were more diverse than those in rural areas. More people in peri-urban Kumasi carried out the skilled and semi-skilled activities, and the urban unskilled labour presented in Table 3.40, than in the rural areas. Income sources based on natural resources were more common in the rural areas then in peri-urban Kumasi, except for livestock production which was carried out on a larger scale in peri-urban Kumasi.

Table 3.40 Income generating activities undertaken by men and women at the five field sites in addition to the sale of crops and livestock

Male income generating activities	**Female income generating activities**
Trading	*Trading*
Trading in durable or processed goods Trading in agricultural commodities	Petty trading (toiletries, soap, sugar) Trading in agricultural commodities
Natural resources/agricultural processing	*Natural resources/agricultural processing*
Palm wine tapping Distilling of *akpeteshie* (local gin) Hunting Charcoal making Livestock production Land rental and sharecropping	Agricultural processing: sale of cooked food, processing of palm oil, cassava and maize, soap making, *pito*[13] brewing Livestock production
Skilled and semi-skilled	*Skilled and semi-skilled*
Hairdressing Sewing Civil servant Teacher Crafts (wood carving, weaving of baskets and cloth) Carpentry Blacksmith Driving Painting Mechanics Masonry	Hairdressing Sewing Civil service Teacher Crafts (pottery and beads)
Unskilled	*Unskilled*
Agricultural labour Construction worker Surface gold mining (galamsie) Sand or stone labourer	Agricultural labour Construction worker Surface gold mining (galamsie)
Capital intensive	*Capital intensive*
Income from tree crops elsewhere Corn milling Transport operator e.g. taxi owner	Income from tree crops elsewhere

Source: field data and Blake et al., 1997 for occupations in peri-urban Kumasi

There were gender differences in the income generating activities practised by men and women (Table 3.40). The most common activities for women were petty trading in small quantities of fish, soap, salt or other commonly used items, processing of palm oil, cassava or maize, and the sale of cooked food. These activities were almost exclusively gender specific.

Men had a much wider range of income generating activities open to them, particularly skilled activities, and men's activities tended to be more remunerative than those commonly practised by women (Blake *et al.*, 1997). When men engaged in trading activities they were more likely to trade in processed or durable goods, or in agricultural commodities on a larger scale than women. Some occupations could potentially be undertaken by men or women, but

[13] A local beer

these were predominantly taken by men. These included agricultural wage labour and surface gold mining *(galamsie)*[14].

The more labour intensive unskilled activities were carried out by the younger age groups. Wage labour was an important source of cash for young people at Oda, and was also used by young people at the other locations. They sold their own labour prior to the farming season or when in need of cash, and then hired labour themselves when there was too much work on their own farm.

Older men were more likely to invest in the more capital intensive activities including ownership of corn mills, tree crops and vehicles. The elderly and infirm, those in urgent need of cash and those with surplus land were the most likely to rent out the land under their control. Older native men probably had larger areas of land under their control as they are favoured by traditional inheritance systems. Older women were more likely to engage in larger scale trading activities.

Northern settlers sometimes had different income sources to native people. At Yabraso charcoal production using savanna trees was an important economic activity undertaken by the Sissala people from the Upper West region. Dagarti women brewed pito for sale. Male settler farmers from the north sometimes sold livestock in their home towns to finance crop production. They also frequently invested the profits of their farming activities in cattle, the acquisition of a bride, other assets or the upkeep of their families in their hometowns in the north.

Loans

Borrowing did not appear to be very common at any of the study sites. Sources of credit included close friends and relatives, money lenders, traders and rural banks. Close friends and relatives often did not charge interest on loans. Other moneylenders charged as much as 50 to 100 % and required collateral such as a bicycle or plantain field. Repayment usually occurred around harvest time. Farmers disliked borrowing from other members of the community as they were likely to be asked to repay the loan any time that they received cash making social relations awkward. However money lenders were also available in neighbouring towns.

Some farmers at Subriso and Yabraso used farm gate traders to prefinance crop production, especially maize and rice. Repayment was in the form of a number of bags at harvest time and

[14] Surface gold mining was carried out only at Oda

was calculated based on current crop prices. Farmers were frequently concerned that they were cheated due to fluctuations in crop prices.

Very few farmers, even cocoa farmers who could supply collateral, had borrowed from rural banks. Although interest rates were as low as 40% or less if repayment was rapid, services were generally considered unsatisfactory and incurred high transaction costs. Loans were considered too small, disbursement too late after the arrival of the cropping season and receipt of the loan often required several trips to a local town to see if it was ready for collection.

3.4.4 Non-income generating activities

Overall, women were responsible for the majority of domestic activities that supported the household whilst men had more free time to relax when they were not working. Non-farm activities reported by a group of young men and women from Subriso are shown in Table 3.41. Women's absence of leisure in this table is consistent with Avotri and Walters (1999) who have described women's heavy workloads and responsibility for the care of others in a small town in the Volta region. Whereas men did physically more demanding work, they were able to take time to rest, whereas women's role in providing constant care for others prevented rest and leisure.

Table 3.41 Non farm activities reported by young men and women at Subriso

Activity	Men	Women
Domestic work		
Cooking	Pounding *fufu*[15]	•
Fetching water		•
Bathing children		•
Washing utensils		•
Cleaning, sweeping and tidying		•
Washing clothes		•
Fetching firewood		•
Productive activities		
Hunting	•	
Barbering	•	
Basketry	•	
Social and community activities		
Going to church	•	•
Going to funerals	•	•
Leisure		
Resting	•	
Listening to the radio	•	
Playing indoor games such as drafts	•	
Visiting friends	•	
Playing football	•	

[15] a staple food in the south of Ghana made by pounding plantain or yam with cassava or cocoyam in a large pestle and mortar

3.5 Livelihoods, land use and the adoption of soils technologies

In this section, farmers' livelihoods and access to resources are discussed in association with the opportunities and constraints they impose for the adoption of soils technologies across the five field sites. The way location, individual farmer characteristics and socio-economic circumstances influence the choice of crop and cropping pattern is discussed in the first section. This is followed by consideration of how access to land, labour and cash and seasonal market fluctuations influence the potential for soil fertility management. The chapter concludes by outlining differences in resource access amongst farmers with different social characteristics.

3.5.1 Crops and cropping patterns

Figure 3.12 outlines factors which influenced, or were associated with differences in crops grown and cropping patterns at the field sites. Location was an important factor which influenced the natural resources available, the risks associated with cropping and links to markets. The attributes of different groups of farmers influenced their access to resources and their roles and responsibilities. Investment in soil fertility is often associated with cash crops (Section 2.1.3), and some methods of soil fertility management, such as cultivation of a cover crop, are specific to particular crops and cropping patterns.

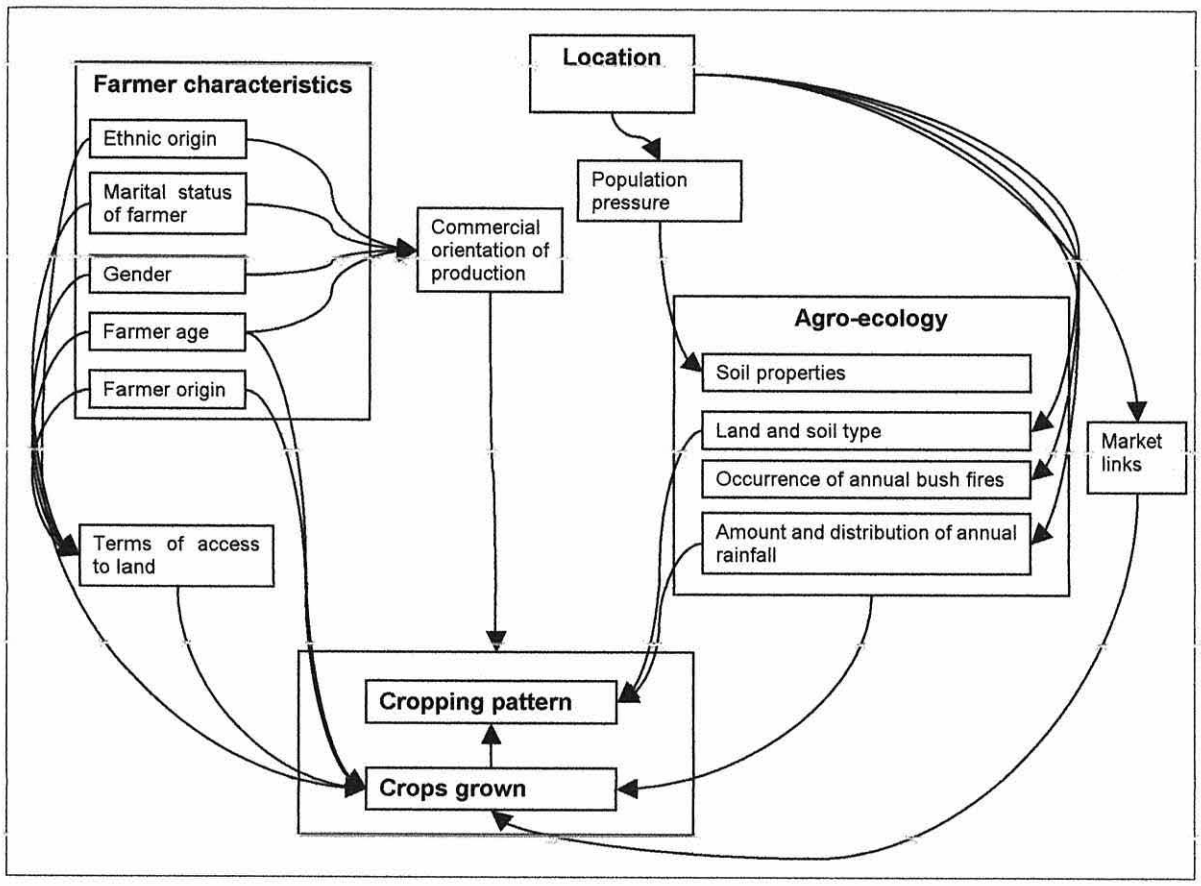


Figure 3.12 Agro-ecological factors, characteristics of farmers and location differences which influenced farmers' choice of crops and cropping patterns at the five field sites. Derived from the results of the livelihoods analysis.

The amount and distribution of annual rainfall had a direct influence on different cropping opportunities, although it was not the only influencing factor. This was reflected in the importance of yam based cropping at Yabraso, and the greater diversity of cash crops at Subriso in the transition zone. Bush fires restricted the cultivation of cocoa to areas they did not reach. The existence of lowland and valley bottom lands in particular villages influenced the opportunities for specialisation in rice, sugar cane, taro, green maize and dry season vegetables. Other soil properties also influenced cropping across the field sites. Plantain was grown in larger quantities at Subriso and Gogoikrom, but did not thrive at Oda and in peri-urban Kumasi.

Marketing links played a very important role in influencing which crops were grown. Taro, green maize and sugar cane were grown for the urban snack market in peri-urban Kumasi. Farmers at the field sites relied to a large extent on farm gate traders for the sale of much produce rather than arranging to transport large quantities of food crops to market themselves. Clark's (1994) research amongst traders and market women in Kumasi found that the origins and locations of different commodities were widely known. Farm gate traders specialising in

particular commodities were only attracted to locations where these were grown as a major cash crop by a large number of farmers. Farmers therefore found that finding buyers was easier when they all specialised in the same crops. This may help to explain why many farmers at Subriso continued to grow tomatoes despite the market being flooded, whereas in peri-urban Kumasi farmers were growing exotic vegetables. At Oda, in the more remote part of the forest zone the quality of the roads was low although (Owusu-Akyaw, 1999) states that markets existed for food crops if farmers could transport them.

Within communities, the commercial orientation of crop production, the ethnic origin of the farmer and the conditions of land access influenced preference and ability to grow different crops, and follow different cropping patterns. This resulted in particular crops and particular cropping patterns being more important to some farmers than to others.

3.5.2 Access to land and investment in soil fertility

The ease with which individual farmers gain access to new land is likely to influence their readiness to invest in soil fertility where shifting cultivation is the main means of managing fertility. Security of tenure beyond a single cropping season may not be necessary for farmers to invest in soil fertility where investments are rewarded in the short term. However some farmers do consider longer term time horizons such as for instance, putting aside a piece of fallow land for their children. Security of tenure may influence farmers' willingness to invest in regular soil management that goes beyond short term profitability such as improving the physical structure of the soil.

However, land rights in southern Ghana are complex and obtaining a clear picture of how different individuals gain access to land, what their use rights are and of trends over time which may indicate changes in land scarcity, is not easy.

One of the problems is that there are no universal, clearly defined and accepted ways of referring to how individuals gain access to land in southern Ghana. For instance, with tree crops caretaking and sharecropping are sometimes confused (Takane, 2000) although they are clearly quite different (Table 3.42). The former is more a means of employment whereas in the latter the tenant farmer gains a long term asset. Sharecropping of long term tree crops and food crops are also quite different in the incentives that they offer. The tenant farmer does not gain a long term asset when sharecropping short term food crops.

Table 3.42 Key differences between caretaking and sharecropping of food and tree crops

Tenure	Crop type	Initial cash payment (*aseda*) required	Provision of inputs (except labour)	Potential for tenant to gain a long term asset (crop parcel)
Caretaking	Tree	No	Landlord	No
Sharecropping	Tree	Yes	Tenant	Yes
Sharecropping	Food	No	Tenant	No

The cost of land rental at the study sites was influenced by expected returns to investment, personal relationships and land scarcity, or as Amanor and Kude Diderutuah's (2001) more detailed study put it, on the basis of the capital involved in cultivation, returns to labour, the scarcity of land and personal ties, trust and reputation. This makes it difficult to use the cost of land rental as an indicator for land scarcity. Furthermore, as Takane (2000) emphasises, there are side benefits to landlords and tenants under some forms of tenure. Under cocoa sharecropping or caretaking an absent landlord's claim to land is strengthened by the visibility of the trees on the land. The tenant benefits from the acquisition of a long-term asset under sharecropping, and from additional land for cultivation of food crops and the opportunity to underreport the harvest when caretaking for an absent landlord.

Subtle changes in land tenure arrangements have also been occurring in response to increasing land scarcity. Amanor and Kude Diderutuah (2001) carried out research in the densely populated Eastern region where the development of citrus and oil palm plantations is considered lucrative. They found that whereas landlords had previously entered into share contracts with settler farmers or young people unrelated to them, sharing arrangements now increasingly involved formalised contracts between close kin. Furthermore, family heads preferred to make money by giving out land for sharecropping rather than allocating land to family members who would not customarily pay for it.

Where farmers use their own land, rather than sharecropping or renting, individual rights differ depending on how the land was acquired. There is a distinction between 'self acquired' property and property that has been acquired from the matrilineal family. Only self acquired property may be passed to others through gift or by bequeathing it in a written will. The recent Intestate Succession Law (PNDCL III) 1985 which increases the inheritance rights of a wife and children only applies to self acquired property (Berry, 1997). A common ground for disputing wills is that property was not self acquired but already belonged to the family. Amongst the Akan, allocated family land has the weakest individual land rights and inherited family land has the second weakest. Tree planted land received as a gift from the father has the strongest individualised rights (Quisumbing *et al.*, 2001).

An additional complication is that land rights and the transfer of land rights between individuals may not be clearly defined, may even be deliberately left open and individuals may act in expectation of changes in land use rights, rather than according to current use rights. It may be many years before inherited land is formally divided up amongst the inheritors. Wives may work on the cocoa plot of their husband and as such develop an interest in receiving a part of the plot in return. However this is by no means guaranteed and may additionally be confused with the labour that a wife customarily provides for her husband without expecting any return. Other individuals may use tree planting as a way of strengthening land use rights (Awanyo, 1998; Quisumbing *et al.*, 2001).

The transfer of land rights is rarely documented and relies on the oral histories of the witnesses to the transaction (Berry, 1997). Even the boundaries between different users may not be marked and disputes over the boundaries between the farm plots of family members are common. Settling competing claims to land rights depends more on an individual's standing with family and neighbours rather than on the way in which the land was originally acquired due to the importance of oral testimony and the common absence of written documents. Hence Berry (1997) argues that rights to land and property are constantly (re)defined and (re)affirmed and that property rights are not a single objective story but are 'defined through on-going processes of negotiation'. Even when sharecropping tree crops, tenants' land rights may be continually contested by the original landholder and the behaviour of migrant farmers is influenced by their need to continually reaffirm their rights to land at the same time as acknowledging the rights of the original landholders in order to avoid a dispute (Awanyo, 1998).

All these issues are likely to have important implications for farmers' security of tenure and potential investment in soil fertility. Where competing or overlapping land rights exist, a farmer may wish to strengthen land use rights at the same time as avoiding any activities which could provoke another to dispute his claim to land or attempt to take it away from him.

At the study sites tenant farmers feared that the land they were using could be taken away from them at any time, suggesting insecurity of tenure. One interviewee had documented evidence that he had rented land for four years, but was nevertheless being asked to return it before that time due to the death of his original landowner and the passage of his plot to another family member. Tenant farmers were able to renegotiate tenancy periods for the same piece of land but feared that if they visibly improved the land they were cultivating, it would be taken away from them. Hence it may be risky for tenant farmers to invest in soil fertility measures where benefits are delayed beyond a single season.

Where farmers are using what they consider to be their own land, but land use rights are overlapping and competing, such as for allocated family land, farmers may also suffer from tenure insecurity which could be an obstacle to investment in soil fertility, particularly where land is visibly improved. At the field sites native farmers appeared to enjoy secure tenure, but one farmer who had grown a good cover of mucuna had her plot taken from her by another family member before she could benefit from it (Obiri-Darko, pers. comm. 2003). Farmers may be unwilling to admit that others have a claim on their land as tenure security is a socially constructed rather than an objective reality. Although trees are a visible sign of land rights, and accepted as strengthening them, this is not yet the case with investments in soil fertility.

Overall, it is difficult to assess native farmers' tenure security. Tree crop plots are likely to invoke the strongest land use rights, particularly when they have been gifted, rather than inherited. Security of tenure on land used for food crops is influenced by the means through which the land was acquired. Tenant farmers have the least secure access to land, and the shortest tenancy periods.

Assessing population pressure on cultivated land is also difficult. Population pressure at individual sites cannot always be predicted. Although Oda was in a sparsely populated district and region, pressure on land was high. Between sites population pressure appeared to be influenced by proximity to urban centres, the length of time an area had been settled, in migration and out migration and whether tree crops were grown.

Different types of land were under differing levels of pressure, with stream side and valley bottom land often in short supply, and upland close to the settlement and roads preferred for the convenience of crop cultivation. Different groups of people within the community had different levels of access to land. Those renting and sharecropping had least access to fertile land. Where land was sharecropped for tree crops the initial cash fee demanded created an entry barrier for some members of the community. Young people and women frequently had more limited access to land than older men who traditionally control family land resources. Access to fertile land by female farmers is also reported as a problem in Nieuwenhuis *et al.* (undated); Goldstein and Udry (1999) and Brook and Davila (2000). Young men and women also often have less access to cash than older men.

Development of a standard and accepted way of referring to different means of access to land associated with different sets of key user rights would improve the utility of research referring

to land access and land tenure. It would make it possible to compare trends in land access over time and in different locations. Furthermore, a set of indicators for assessing land scarcity between different communities could be of use in the targeting of soil fertility research and development activities. Amongst native farmers, young people and women are likely to be the first to feel the influence of increasing land scarcity. Potential indicators might include:

- the cost of the initial cash payment (*aseda*) for sharecropping tree crops,
- whether young people and women can obtain (afford) land to cultivate tree crops,
- the existence of formalised sharecropping contracts between close kin for tree crops,
- the proportion of farmers sharecropping rather than renting land for staple crops such as maize and
- the proportion of native people (especially young people and women) using sharecropping, renting and other means to obtain land for upland crops.

3.5.3 Labour and farm management

Access to labour was clearly a considerable constraint at all the field sites. Labour was in plentiful supply from young people and northern migrants during the periods of greatest seasonal demand, but it was the ability of farmers to pay for it that was the main constraint. The period of greatest labour demand also coincided with the time of least cash and food availability. Maintaining cash flow throughout the year was therefore necessary to hire labour at this time, and few farmers could manage this.

Farmers suggested increased school enrolment as one reason for decline in access to labour. Amanor and Kude Diderutuah (2001) suggest an additional reason linked to the strong connections between the economies of land and labour. They suggest that since the 1970s the youth and the elders have been struggling over access to land and labour, both of which have become scarcer. Young people who would once have worked on family farms are now unwilling to do so, and prefer to work as share tenants or casual labourers on the farms of non-family members. With increasing land scarcity they are no longer allocated sufficient land from their own families. Elders are also reluctant to release land to sons and nephews who are not working for them, as they would loose the additional revenue that could be generated from leasing the land to non family members.

Awanyo (2001) shows how access to labour in southern Ghana is socially embedded and how conflicts between individuals frequently result in the withdrawal of labour, particularly amongst low income groups who have greater difficulty in mobilising resources to meet their

responsibilities and obligations to both conjugal and matrilineal families. When there is conflict between husband and wife e.g. over income distribution and expenditure, the wife can withdraw the labour she customarily provides on the farm. Similarly, in the context of increasingly expensive wage labour, if hired labourers feel they are not receiving sufficient reward for their work, they reduce the quality of work done on the farm. This results in increasing time spent in supervision of labourers, and reluctance to hire labour for tasks requiring careful attention, such as weeding very young crops which will easily be damaged by careless use of the cutlass.

Shortened fallow periods result in an increase in weed problems and therefore add to labour and management requirements. Hence, those with the weakest access to land may have increased labour demands. At the field sites these included northern settler farmers sharecropping and renting at Subriso and Yabraso, young people at Oda, and women farmers who had weaker rights to land and preferred to crop closer to the settlement where land has been more intensively used. Increased weeding requirements and reliance on hired labour would also lessen the profitability of cropping. Therefore soil fertility technologies that reduce weeding requirements may be more likely to appeal to farmers who have limited access to good quality land. However, technologies that are risky, require more labour input than farmers' practice at some stage of the technology, or require precise or complex management, are more likely to appeal to those with good access to their own labour.

The gender division of labour should also be considered when introducing new technologies as it may influence the feasibility of the technology, whose labour is used, and who benefits from it. Where wives customarily provide labour on their husband's farm, technologies which replace the wife's labour with additional investment from the husband may not be of interest to men. Technologies which increase women's labour requirements without benefiting them will not be equitable to women.

The different sources of labour used by different categories of farmer may also influence the appropriateness of different technologies. Women and older men relied more on hired labour. Older men also had access to more labour than their wives and family. Younger men relied more on their own labour. Women were less able to provide close management of the farm than men due to the other demands on their time. Older men may therefore prefer to use technologies which involve cash outlay but reduce the need for hired labour, whereas younger men may prefer technologies which involve use of their own labour but reduce cash outlay.

3.5.4 Access to cash

Access to cash differed with age and gender. Older men were generally more likely to control family assets such as land, and to have off-farm income sources. Care of the household was an important opportunity cost on women's time lessening their ability to engage in their own income generating activities. They were also more likely than men to use crops from their own farm and their cash income to support themselves and their children, rather than to expand their farming or trading enterprises. Young men also had less access to cash than older men, but could sell their own labour in times of need. Agricultural technologies that require cash inputs may therefore be more appropriate to men than women. The role of young men in commercial tomato production which relies on agro-chemicals suggests that lack of cash may not be such a barrier for young men, at least where a technology is profitable.

3.5.5 Access to markets and seasonality in crop prices

Marketing was an important determinant of the profitability of food crop farming at the field sites. Farmers countered seasonal fluctuations in the prices of food crops by storing crops to wait for high prices, producing out of season and processing food stuffs such as cassava and oil palm. Evaluation of the profitability of new technologies must therefore consider the time of crop sale. Farmers may need to store crops such as maize, in order to benefit from yield increases brought about through investment of additional resources. Crop storage is only possible however where farmers are able to obtain cash from other sources, such as additional crops or off farm employment whilst the crop is in storage.

An additional implication for the design of soil fertility technologies is that technologies that help farmers to produce out of season may find favour with farmers but those that alter the harvesting dates of such crops deliberately timed to fetch the highest prices will not. For other crops, farmers may need to solve marketing constraints before they are able to benefit from increased yields. Dorward *et al.* (2003) found that marketing constraints were more of a constraint to profitability than soil fertility was in some villages in the Brong Ahafo region.

3.5.6 Broader livelihood strategies

Agriculture is clearly important in Ghana. It accounts for around 35% of GDP and cocoa forms around one fifth of the value of total exports (World Bank, 2002a). It employs a large proportion of the workforce, being the primary or secondary occupation of many people in urban, peri-urban and rural areas. Around one third (32%) of persons in urban areas own or operate a farm or keep livestock, 86% in the rural forest and 93% in the rural savanna (Ghana Statistical Service, 2000). However agriculture is not an occupation of choice for all people.

Young people in particular are less interested in agriculture, and prefer occupations in towns and cities. Furthermore, the high degree of mobility within the population moves cash and labour in and out of agricultural investments in local communities. Short term and long term interest in agriculture may influence individual's interest in investing in soil fertility management. Farmers whose livelihoods depend on cropping may be more interested in investing in sustainable soil management than those who are planning to move to other occupations.

In this research standard Participatory Rural Appraisal techniques commonly used in agricultural research were used to learn about access to resources and agricultural practices and how these differed between and within communities. These research methods were sufficient for the purposes of this research which was to provide a picture of diversity in rural livelihoods and resource access and to understand how this influenced soil fertility management opportunities and constraints. However farmers' decision making is also influenced by livelihood strategies and off-farm employment opportunities, for example, in the adoption and disadoption of mucuna in northern Honduras (Section 2.2.2, Neill and Lee, 2001). Identifying livelihood strategies could capture a more dynamic picture of livelihoods than a snapshot view of resource access. It might help to distinguish between social groups with different opportunities and constraints for the productive use of natural resources.

3.5.7 Understanding women's land based livelihoods

Understanding women's livelihoods and access to resources is necessary for effective decision making about investments that could benefit women. Focusing on improving women's agricultural production may be inappropriate if alternative opportunities such as trading are a more efficient or effective use of women's resources. Overå (1995) draws attention to the 'dual-sex system' of employment in Ghana where men and women are engaged in different economic activities for which they each have respective advantages, and do not therefore compete at the same activity. Men have better access to the resources for crop production, particularly for cash crop production as they have better access to labour and are favoured by land allocation practices and women may therefore find it difficult to compete.

Detailed research has improved understanding of how women have become successful in the traditionally female occupations of trading and fish processing in southern Ghana (Clark, 1994; Overå, 1995). However, the land based livelihoods and productive agricultural activities of men in rural and peri-urban areas are still better understood than those of women.

In particular the livelihoods of married (or other dependent) women and young women are not well understood. Women have less time to participate in research than men and not all women have farm plots of their own, so that although the majority of women provide labour on the farms of their husbands in rural areas, they are less frequently the decision makers and their contribution is therefore often less visible than that of men. Gender focused research may be necessary to understand the roles and access to resources of different social categories of women in modern rural Ghana, and to understand if and how women can take advantage of agricultural opportunities. This research should, however, be careful not to abstract women's livelihoods from those of men and other dependents as this can result in an incomplete understanding of the situation of women and lead to inappropriate interventions (Peña *et al.*, 1996).

3.6 Estimating the adoption potential of soils technologies for disaggregated groups of farmers

This chapter has shown that the land based livelihoods of individuals and households at the forest margin in southern Ghana are diverse and complex. This has implications for the appropriateness of agricultural technologies to the livelihoods of different individuals.

In general, livelihoods in rural areas are largely dependent on agriculture, and more particularly on crop cultivation. Off-farm opportunities become increasingly important in peri-urban areas. There are different ways of gaining access to land, and although pressure on land is increasing, it is heterogeneous between locations, for different types of land, and between individuals. Seasonal labour constraints are felt by most farmers as they lack cash to hire labour at weeding time. Although the time of least cash availability is prior to harvest, particularly for farmers who depend only on income from crops, lack of cash is seen as a problem more generally throughout the year for all farmers. Large seasonal fluctuations in the farm gate price of most food crops entails that the time of crop sale has a large influence on crop profitability.

Access to key resources is achieved in different ways by different individuals within locations. Grouping individuals according to gender, age, marital status and origin gives some indication of crops grown, cropping patterns and access to resources. Table 3.43 suggests a list of factors that could influence the adoption potential of a technology and are primarily determined by farmers' social attributes. Farmers dependent on hired labour, but who lack access to it are likely to have the greatest labour constraint, and both farmers dependent on hired labour and farmers with labour constraints are likely to have limitations on their

management abilities. However dependency on hired labour can differ with different crops, with farmers more dependent on hired labour for commercial crops than for subsistence orientated crops.

Table 3.43 The influence of farmers' social characteristics on the adoption potential of soils technologies

Factor influenced by farmer's social characteristics	**Outcome**
Farmer is dependent on hired labour but lacks access to it at the time when it is needed	Farmer has a labour constraint
Farmer is dependent on hired labour	Farmer has a management constraint
Farmer has a labour constraint	Farmer has a management constraint
Seasonal dependency on access to hired labour at times when it is not available	Farmer has a seasonal labour constraint
Assets accumulated through agricultural activities are used in the long term to invest in livelihoods elsewhere with the intention to migrate	Low potential interest in long term land management
Long term livelihood strategy in which agricultural and off-farm sources of income are mutually reinforcing	Potential interest in long term land management

Both men and women rely on hired labour, but for different reasons (Figure 3.13). Women do not usually clear land themselves, and the opportunity cost on women's time of childcare, domestic tasks and labour provided on their husbands' farm, reduces their ability to use their own labour. Older men, on the other hand, cultivate larger areas and so require hired labour to complete farm tasks. Younger men have less access to cash than older men and rely more on their own ability to do physical work. In some locations where labour is provided by seasonal migrants it is not available during some times of the year when these labourers have returned to their homes. However for most labour constraints access to cash is the problem, rather than unavailability of labourers.

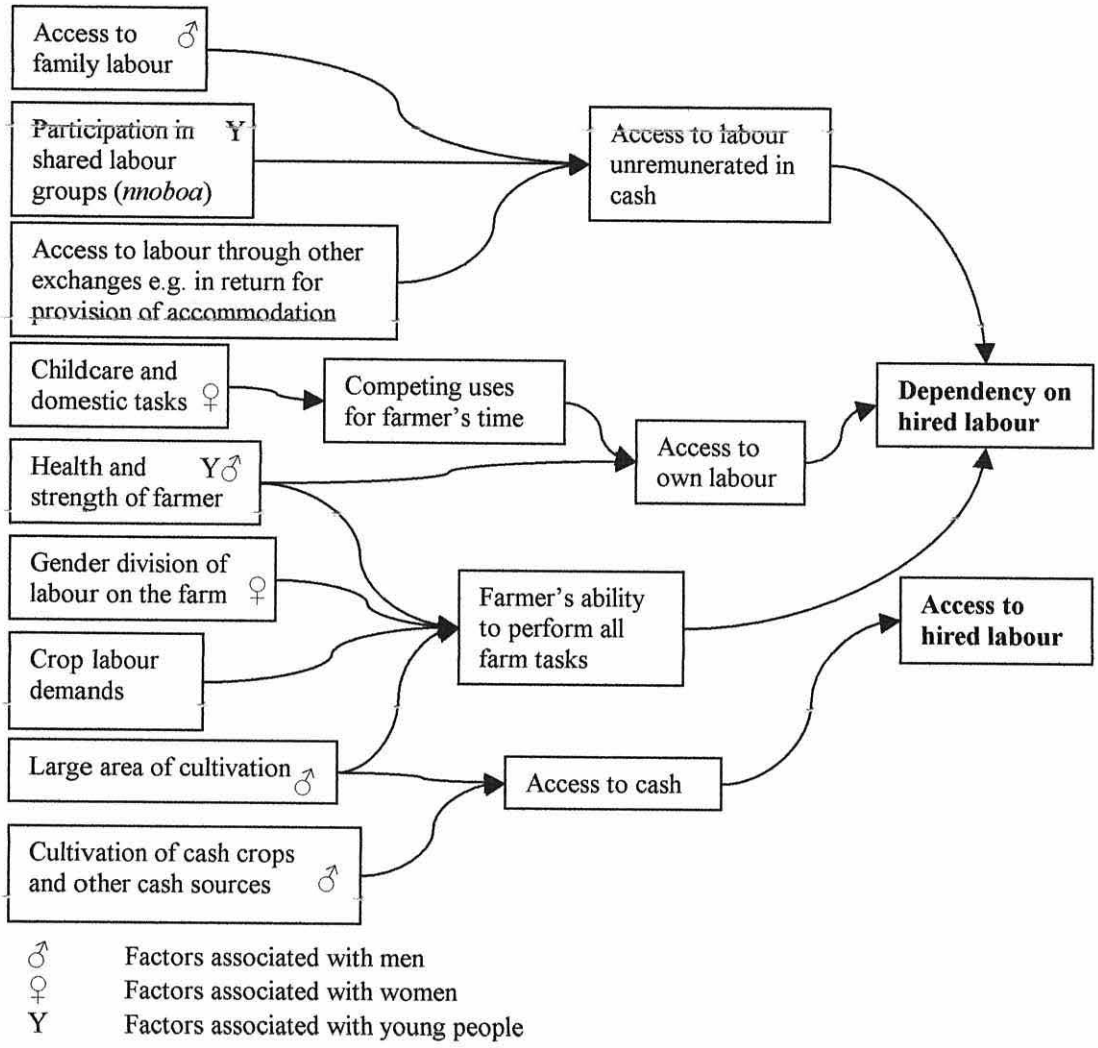


Figure 3.13 Factors influencing the ability of men, women and young men to get access to hired labour and their dependency on hired labour. Derived from the results of the livelihoods analysis.

The crops grown and cropping patterns used by farmers are influenced by agro-ecology and market links and also by farmers' social characteristics (Section 3.5.1). Crop characteristics relevant to farmer decision making about soil fertility are listed in Table 3.44. Ghanaian farmers have tended to invest agro-chemicals in cash crops only. Large seasonal fluctuations in crop prices occur which influence the profitability of different crops and the risk associated with cultivating perishable crops. Where a farmer has restricted decision making power over the disposal of a crop or proceeds from crop sale they may have a low interest in investing additional resources in its cultivation. Similarly where unremunerated family labour is used to cultivate a crop, technologies which require additional labour resources may be evaluated differently by different people involved in their cultivation. Some crops are cultivated both for

subsistence and for cash, and the emphasis on subsistence or commercial farming may depend on the social characteristics of the farmer.

Table 3.44 The influence of characteristics of crops on the adoption potential of soils technologies

Factor influenced by crop characteristics	Outcome
Crop cultivated mostly for subsistence	Low interest in high external input technologies for increasing production
Crop is a significant source of cash income either now or in the future	Potential interest in investing additional inputs in cultivation
Perishable cash crop for which market price experiences large fluctuations	Additional inputs will increase production risks
Storable cash crop for which market price experiences large seasonal fluctuations	Profitability may be linked to cash flow and storage technology
Cash crop is harvested early in the harvest season, or else out of season	Profitability may be linked to the time of sale
Crop is harvested during the main harvest season	There may be advantages to interventions which enable production out of season
Farmer has restricted decision making power over disposal of proceeds from crop sale	Low interest in investing additional inputs in cultivation
Unremunerated family labour is used for cultivation	Technologies which increase unremunerated labour input may have a negative impact on welfare. However technologies which reduce unremunerated labour input may not be seen as advantageous by the farmer

Both farmers' terms of access to land, and farmers' perceptions of soil properties influence interest and ability to invest in soil fertility technologies (Table 3.45). Farmers are more likely to invest in soil fertility where they perceive that soil fertility is a problem, and this is likely to be crop specific. The duration and security of tenure that farmers have will influence the type of land management that they are able to benefit from. Furthermore, where farmers pay for access to land, this will influence the profitability of investment in land management in comparison with situations where farmers make no payment for land access.

Table 3.45 The influence of characteristics of crop land on adoption potential of soils technologies

Factor influenced by characteristics of crop land	Outcome
Farmer perceives some form of soil fertility problem on crop land for a particular crop	Potential interest in soil fertility interventions
The period of tenure is short term.	Low interest in medium to long term land management
The period of tenure is long term	Potential interest in long term land management
Farmer's tenure is temporarily secure but other individuals may make a claim on the land in future.	Low interest in long term land management
Farmer has very secure tenure in the long term	Potential interest in long term land management
Farmer makes seasonal or annual payments for access to land	Influences the profitability of inputs used in production.

Overall this chapter has shown that multiple factors influence crops and cropping patterns and therefore the livelihoods of individual farmers at the forest margin in Ghana. Location and the social characteristics of individuals are important for their influence on the availability of natural resources, market links, access to resources and other roles and responsibilities. Consideration of this diversity within land based livelihoods, particularly diversity in crops and cropping patterns, and in access to resources, could result in more appropriate agricultural research and development of soil fertility management technologies relevant to smallholder farmers.

4 LOCAL KNOWLEDGE AND THE ADOPTION OF SOIL FERTILITY MANAGEMENT TECHNOLOGIES

It is now recognised that local knowledge can contribute to agricultural research and development in many ways (Warburton and Martin, 1999). Local knowledge of soils has been a fast expanding area of research in the last 20 years and there is a substantial quantity of documentation in the published and grey literature with Barrera-Bassols and Zinck (2003) finding 895 references. This chapter begins by outlining how finding out what local people know about soil fertility management at the forest margin in Ghana can contribute to this research on understanding and improving the adoption of soils research outputs.

Enhancing understanding of farmer decision making

Previous local ecological knowledge research has shown that farmers make trade-offs in their management of ecological resources in order to satisfy multiple objectives. Thapa *et al.* (1997) described how Nepalese farmers in the mid hills of Nepal managed fodder trees in association with crops on terrace risers. They knew that trees with large leaves promoted splash soil erosion, but prioritised fodder production at the expense of crop production and soil conservation as many trees with large leaves also had high fodder value. In their decisions about which trees to retain on farm, farmers had to make trade offs between fodder production, crop production and soil conservation. Similarly, research in Indonesia has found that rubber farmers use agro-ecological knowledge in the management of the weeding of rubber seedlings which are vulnerable to damage by pigs when clean weeded (Joshi *et al.*, 2002). These examples illustrate cases where farmers may have appeared to be making sub-optimal use of available natural resources due to lack of ecological knowledge, but were actually making deliberate trade-offs. Farmers' actions represent a complex set of compromises involving consideration of ecological, economic and social factors occurring throughout the growing season (Sinclair and Walker, 1999). Understanding local ecological knowledge can help researchers and development workers to understand the rationale behind farmers' decision making.

Identifying gaps in farmers' knowledge

Eliciting local knowledge has also revealed where farmers lack knowledge. Nepalese farmers' have been found to hold relatively sparse knowledge of below-ground interactions in comparison to their more sophisticated knowledge of above-ground tree-crop interactions

(Joshi, 1997). Other research has shown that they know and understand surface runoff but have little understanding of leaching (Shrestha, 2003).

It has been suggested that scientists' and farmers' different methods of observation, and different standards for drawing conclusions can explain some of these differences in knowledge (Bentley, 1994; Joshi *et al.*, in press). Sinclair and Walker (1999) suggest that very small organisms, processes that take place within the soil and processes that occur over very long periods of time, may be difficult for farmers to observe. They may therefore lack knowledge of pests and diseases, particularly where these are too small to see with the naked eye, soil processes, and issues to do with sustainability.

Nevertheless, where farmers can clearly distinguish causes, and observe the effects on a regular basis, they have been able to draw powerful conclusions from their observations, despite the limitations imposed on viewing the processes in between. Nepalese farmers are able to classify tree fodder according nutritiousness (*posilopan*), and ability to satisfy animal appetite (*obanopan*), merely by observing what is fed to the animal, and its subsequent behaviour (Thapa *et al.*, 1997; Thorne *et al.*, 1999). Their knowledge is holistic rather than reductionist. However, inability to distinguish cause and effect, limited observation of causal processes, and multiple invisible processes all make experimentation difficult for farmers. Understanding local ecological knowledge can highlight areas where farmers lack knowledge and where research results from the scientific community have yet to be extended to farmers.

Improving the relevance of scientific research

Comparing the knowledge of farmers and scientists has also highlighted differences and complementarities and led to research that is more relevant to farmers' objectives. Nepalese hill farmers were found to have sophisticated knowledge of tree fodder but also valued tree fodder differently to livestock scientists (Thapa *et al.*, 1997; Thorne *et al.*, 1999). Farmers valued fodders which satisfied the appetite of the animal in times of feed shortage but which had low digestibility. Conversely, livestock scientists valued fodders with high digestibility which could, therefore, be expected to contribute more to animal nutrition. Thus farmers operating in an environment of seasonal fodder shortages used their agro-ecological knowledge to satisfy a broader range of objectives than had been previously considered by livestock scientists. A comparison of farmers' and scientists' knowledge of soil fertility management in Ghana might also contribute to understanding the relevance of scientific research to farmers' objectives.

The next part of this chapter explains the Knowledge Based Systems methodology that was used to elicit local knowledge of soil fertility. This is followed by a brief overview of the soil fertility management practices that were carried out in the study area, and then by information on farmers' sources of knowledge from both within, and outside of the local community. These latter two sections, in addition to Chapter 3 provide important contextual information for understanding the extent and depth of farmers' knowledge. They are followed by presentation of farmers' qualitative knowledge, and quantitative analysis of its distribution. Finally, the knowledge and its implications for the relevance of soils research, and its dissemination, are discussed.

4.1 Methodology

Research on local knowledge has come from quite different disciplines which include anthropological and natural science traditions (Talawar and Rhoades, 1998). Different terminology has been used to refer to local knowledge including indigenous knowledge, indigenous technical knowledge and folk knowledge. Different disciplines have placed different emphases on what constitutes local knowledge. It is, therefore, necessary to clarify what is meant by 'local agro-ecological knowledge' in the context of this research, and the methodology used.

Agro-ecological knowledge is knowledge about the ecological processes that take place within farming systems, together with knowledge of the animals, plants, soil and other elements which make up those systems. Descriptive agro-ecological knowledge relates to the properties of crops, animals and soils. Explanatory agro-ecological knowledge has predictive power unlike heuristic rules of thumb[16], and frequently relates to ecological processes (Sinclair and Joshi, 2000). Knowledge about the natural world which has practical explanatory and predictive power is distinguished from preferences, cultural values and norms, and from supernatural knowledge (Joshi *et al.*, in press). Supernatural knowledge may also be used in an explanatory way, but Joshi *et al.* (in press) state that 'in practice, farmers tend to reply to pragmatic questions about the ecology of their farming systems with answers based on natural rather than supernatural explanations'.

Finally, local knowledge is defined as the knowledge held by the people living in a particular social and/or geographic, locality (Joshi *et al.*, in press). Farmers gain local knowledge through observation of the environment, through the evaluation of the outcome of their actions, and through the exchange of knowledge with other people or media. These may

include sources external to the locality such as radio, television, printed media or visiting researchers and extension workers. Some authors place emphasis on knowledge that is passed from one generation to another (e.g. Braimoh, 2002). However, it seems that contemporary observation of, and interaction with the environment, may be at least as important an influence on farmer's current knowledge as that which is passed on from generation to generation. Due to the way in which it is obtained, local knowledge is very much a dynamic resource that is constantly changing and evolving with time (Joshi *et al.*, in press).

4.1.1 The use of a Knowledge Based Systems approach

A knowledge based systems approach was used to document and then analyse local knowledge of soil fertility management at each of the five field sites mentioned in Chapter 3 using the Agroecological Knowledge Toolkit (AKT5) methodology and software. A broad overview of the AKT5 approach will be given here, to be followed by a more detailed account of how it was used in Ghana in the following sections.

Using the AKT5 method, the researcher carries out detailed interviews with local people about their agro-ecological knowledge. This knowledge is abstracted from the researcher's notes or tape script and entered into a computer file called a knowledge base as a set of statements written using a formal grammar. These statements are accompanied by information about the definition and classification of the terms used. During creation of the knowledge base, iteration and triangulation are used to produce a comprehensive, detailed and coherent record of the knowledge. The researcher focuses on a small number of informants from a limited geographical area in order to obtain a sufficiently detailed and comprehensive understanding. Once satisfied with the detailed knowledge base, the researcher can then use it to test the distribution of the knowledge it contains over a larger sample of the population. This is done by using the knowledge base to develop a questionnaire which is then administered to a larger randomised sample of people. The basis of the AKT5 approach has been outlined in Sinclair and Walker (1998) and Walker and Sinclair (1998) and the mechanics are described in detail in the manual accompanying the software (Dixon *et al.*, 2001).

4.1.2 Preparation for knowledge elicitation

Prior to eliciting local knowledge, the researcher enters a preparation phase. He or she familiarizes him or herself with the source community. Basic information is gathered about

[16] Rules that people follow without knowing how they work.

the livelihoods of the farming population and their cropping practices. Variations in knowledge generally exist between and within communities. In any particular case the factors that affect knowledge on a particular topic need to be identified so that the population can then be stratified, and the key informants can subsequently be selected from different groups during knowledge elicitation. A preliminary assessment of what is known by the whole community is carried out. The objectives of the research are then refined (Walker and Sinclair, 1998). During the present research, the analysis of land based rural livelihoods in Chapter 3 served to provide sufficient information about the local population and the organisation of farming practices to proceed to eliciting and recording knowledge.

4.1.3 Eliciting and recording local knowledge

During this stage of the research, detailed local agro-ecological knowledge was elicited from informants and recorded in five separate knowledge bases using the AKT5 software. This was carried out by four different researchers (Section 4.1.3.1). In the following sections, the field sites where interviews were carried out are detailed, and the stratification of informants and the type of interviews used are described.

4.1.3.1 Field sites

Separate knowledge bases were created for each of the five field sites used for the analysis of livelihoods and land use (Section 3.3.4). Farmers were interviewed from the villages used for the analysis of livelihoods, and in some cases, from additional villages in the same area with similar cropping practices, as local agro-ecological knowledge has been found elsewhere to vary more amongst sites than within them (Joshi, 1997). As with the livelihoods research (Section 3.1.3), the author of this thesis was part of a multidisciplinary team and made different contributions to the knowledge bases created at the different field sites. The knowledge bases created for the Oda and peri-urban Kumasi sites were created wholly by the author. The knowledge bases for Subriso and Yabraso were created jointly with other team members (Obiri-Darko *et al.*, 2000). The knowledge base for Gogoikrom was created entirely by another team member (Frost, 2000). Following the creation of these five knowledge bases, an additional knowledge base was created by Saunders (2002) to clarify farmers' knowledge of the interaction between trees and crops on cocoa farms through interaction with farmers from two further villages of the Atwima district. The results of this research contribute to Section 4.4.4.

Wassa Amenfi district

Farmers from four locations were interviewed in the Oda area and the three villages are described in Table 4.1. Cocoa was the most important crop at all the locations, and all villages

were within 20 km of the district capital of Asankrangua but with increasingly difficult access. The fourth and furthest location, Tano Agya, consisted of an area of scattered hamlets on cocoa farms bounded by the river Tano and the Tano Anwia forest reserve and was administratively within Aowin-Suaman (Enchi) district although access was obtained by crossing by canoe from Oda.

Table 4.1 Characteristics of the research villages in Wassa Amenfi district

Village	Oda Kotoamso	Asankran Bremang	Afiena
Distance to district capital Asankrangua	10 km	6 km	12 km – the village sits on an extremely steep hill which cannot be driven up except by 4WD vehicles.
Population	2000	6000	1000
Proportion of settlers	<10%	N/A	40%
Main ethnic group	Wassa	Wassa	Wassa
Other ethnic groups	Ashanti, Brong, Dagarthi, Fanti and Ewe	Ashanti, Brong, Dagarthi, Krobo, Ewe, Kusasi, Fanti	Krobo, Ewe, Akweapim, Brong, Dagarthi, Grusi, Frafra
Most important cash crops	Cocoa, maize, oil palm, cassava	Cocoa, rice, maize, vegetables	Cocoa

Peri-urban Kumasi

Farmers were interviewed from four villages on main roads between 11 km and 27 km from Kumasi at the peri-urban Kumasi field site (Table 4.2). A variety of cash crops were grown at these sites, with either maize or cassava important at all sites, and valley bottom land available for rice at two of the villages. The village of Abuakwa had nearly been taken over by Kumasi city itself and there was little agricultural land left.

Table 4.2 Characteristics of the research villages in peri-urban Kumasi

Village	Boankra	Besease	Aboaso	Abuakwa
District	Ejisu Juaben	Ejisu Juaben	Kwabre	Atwima
Distance from central Kumasi	27 km east on the road to Accra	21 km east on the road to Accra	19 km north on the road to Mampong	11 km north-west on the road to Sunyani
Population	3000	4000	3500	15,000
Proportion of settlers	20%	20%	57%	40%
Livelihoods	Majority full-time farmers. Some commuters working in Kumasi.	Majority full-time farmers. Also many commuters working in Kumasi	Majority full-time farmers.	Majority engaged in off-farm occupations. Some full-time farmers.
Main cash crops	Okro Cassava Rice	Cabbage Cassava Rice	Cassava Maize	Vegetables Maize
Livestock	Small scale sheep and poultry	Small scale sheep and poultry Some pigs and cattle	Small scale sheep and poultry Flocks of sheep Cattle A few intensive poultry farms	Small scale sheep and poultry Flocks of sheep Cattle 3 intensive poultry farms

Atwima district

Farmers were interviewed from two villages in the Atwima district (Table 4.3). At both villages cocoa was an important cash crop, and there were also valley bottom areas used for rice and maize on residual soil moisture.

Table 4.3 Characteristics of the research villages in Atwima district

Village	Kyereyase	Gogoikrom
Distance from Kumasi	26km on surfaced road and 6km on a good unsealed road	40km on a surfaced road and 10km on a small unsealed road
Population	>40 households	60 households
Proportion of settlers	<50%	<50%
Main cash crops	cocoa rice	cocoa rice

Source: Frost (2000)

Subriso and Yabraso

At the remaining two study sites, farmers from the single villages of Subriso No. 3 (Tano district) and Yabraso (Wenchi district) were interviewed.

4.1.3.2 Informants and interviews

Semi-structured interviews were used to elicit local ecological knowledge from farmers. Interviews were mostly with a single farmer, but sometimes with two or three farmers together. Farmers were initially asked about their current land use practices and the crops they were growing. Then a check list of soil fertility topics was used to guide the interviews. Informants were encouraged to talk at greater length on subjects that were of interest to them

or that they were knowledgeable about. Interviews were carried out in Twi using an interpreter. Twi is the language of the Ashantis and is widely spoken in southern Ghana. Interviews were either tape recorded and later transcribed or else notes were made in the field. Later on statements of knowledge were abstracted from the interviews and entered into a knowledge base. During this process a checklist of additional questions was formed to clarify points and obtain more detailed information. The interviewer then returned to approximately half of all interviewees to clarify points made in initial interviews and explore topics in more detail. At some sites, where knowledge obtained was unclear or contradictory, groups of farmers were interviewed in order to promote discussion and clarify the knowledge.

Where it is suspected that different classes of people within the community may hold different knowledge about the subject of research, informants are stratified to ensure that there is full coverage of the knowledge available (Dixon *et al.*, 2001). Stratification also ensures that all classes of people are considered in the research. A number of different factors were initially identified that might influence the knowledge held by informants:

- The gender division of labour on the farm might influence the knowledge held by men and women (Section 3.4.3.4).
- Farmers who have migrated from other areas where there are different cropping systems and different soil fertility management practices may have different knowledge to native farmers.
- Older farmers with more farming experience may have more knowledge than young farmers.
- Different soils and soil fertility practices are associated with different crops and may also influence farmers' knowledge, therefore farmers operating different cropping practices may have different knowledge (Section 4.4.1).

Overall four categories of farmer were used at each of the field sites (Table 4.4). Gender was considered everywhere. Farmer origin was considered at Tano and Wenchi where northern settlers formed a reasonable proportion of the population. Age was considered at both Wassa Amenfi and peri-urban Kumasi where there were fewer settlers and a marked difference amongst older and younger people. At Wassa Amenfi, the vast majority of farmers cultivate cocoa, but at peri-urban Kumasi cropping patterns are more diverse. Some of this diversity is linked to differences in age and gender, and although during interviews crops grown was not considered as a separate strata, farmers were deliberately selected to represent the full range of crops grown. At Atwima crops grown were considered, with cocoa and rice farmers forming the two strata.

Interviewing five informants from each stratum is considered sufficient at this stage where knowledge is being elicited and recorded in knowledge bases. Past research has found that larger numbers of similar informants produces little new knowledge (Walker and Sinclair, 1998). Therefore approximately 20 farmers from four strata were interviewed at each site.

Table 4.4 Stratification of farmers at each site

Site	Gender	Farmer origin	Age	Crops grown	Number of strata
Oda	√		√		4
Gogoikrom	√			√	4
Peri-urban Kumasi	√		√		4
Subriso	√	√			4
Yabraso	√	√			4

The criteria for farmer selection within strata was largely based on informants' willingness to participate. This is an essential requirement as interviews are detailed and time consuming, and it is often necessary to return to the same informant on more than one occasion. Articulate informants also aided the interview process. As the aim of the research was to obtain a picture of the knowledge held by the majority of the community there was no attempt to select particularly 'knowledgeable' farmers. In any case problems have been associated with asking local people to identify suitably knowledgeable farmers as knowledgeability can be confused with social status (Joshi, 1997). Lack of knowledge amongst farmers was more fully covered in the final generalisation stage (Section 4.1.6).

4.1.4 Retrieval and comparison of knowledge from five knowledge bases

Knowledge from the five knowledge bases was evaluated with the aid of specially written automated reasoning 'tools'. These were small program segments written in the task language of the AKT5 software, similar in concept to macros in well known software packages such as Excel or Word. These tools facilitated the retrieval and comparison of knowledge from the different field sites.

4.1.5 Soil samples from farmers fields

Soil samples were taken for laboratory analysis from four villages in the Brong Ahafo region during April 2002 (Table 4.5). Farmers' assessments of the properties of the soils sampled were elicited during group interviews at each of the four villages with a mixture of male and female farmers. The farmers named and described each type of soil in the area and its properties. Later on one example of each soil type named was sampled. Sampling was carried out by a technician from the Soil Research Institute, Kumasi. In accordance with the advice of

the technician samples were taken at depths of 0 – 15cm and 15 – 30cm (except at Johnsonkrom where only the upper soil layer was sampled). Three replicates were taken of each soil type 2 m or more from one another. Samples were not bulked. During sampling a description of the land and soil was elicited from the accompanying farmers including its cultivation history. This description was most frequently given by the farmer who was currently cultivating the land.

Table 4.5 Location of soil sampling and samples collected

Village	District	Red soil	Black soil	Sandy soil	Clayey or waterlogged soil	Stony soil	Number of samples
Johnsonkrom	Sunyani	1	1	1	0	1	4
Monta	Tano	1	0	1	1	0	3
Sereso	Sunyani	1	1	1	1	1	5
Susuanso	Tano	1	1	1	1	1	5
Total		4	3	4	3	3	17

Soil samples were analysed at the University of Wales, Bangor. Tests conducted were gravel content, moisture content, organic matter, pH, electrical conductivity (EC), available nitrogen, phosphate and potassium, water holding capacity, and textural classification (Table 4.6).

Table 4.6 Laboratory soils analysis methods

Test	Laboratory methods
Gravel content	Sieved for stones of >5mm
Organic matter	Combustion (furnace)
pH	Measured in a 1:1 (v/v) soil to water extract
EC	Measured in a 1:1 (v/v) soil to water extract
Available N	Extracted with 1M KCl using a (w/v) 1:10 soil extractant ratio and colorimetric analysis with a segmented flow injection analyzer (Skaler Corp)
Phosphate	Olsen P method
K	Measured in a 1:10 (w/v) 1M acetic acid extract
Textural classification	Hand texturing

4.1.6 Testing knowledge distribution

Initial eliciting and recording of local knowledge involves talking to a relatively small number of farmers in depth. To test the extent to which the knowledge that has been elicited is common knowledge amongst all farmers, or known by an identifiable subset, a much larger sample is interviewed. Where different strata exist in the farming population it is possible to test whether some groups of farmers are more knowledgeable on some subjects than others. The final stage of the methodology is, therefore, known as the generalisation stage and involves testing the representativeness of knowledge across a wider group of informants (Walker and Sinclair, 1998).

In order to test knowledge distribution a structured questionnaire was designed based on the knowledge recorded in the five knowledge bases. The questionnaire was then administered to 210 farmers from five contrasting locations which differed in terms of agro-ecology, tree cover, population density and market access. The fieldwork for testing knowledge distribution was carried out entirely by the author (with the aid of field enumerators). The questionnaire, its administration, the area over which it was administered and data analyses are described in the following sections.

4.1.6.1 Questionnaire design

A structured questionnaire was designed to explore how widely held the knowledge was that was contained in the five knowledge bases that had been developed in the acquisition phase (Section 4.1.3). The questionnaire had six sections. The first of these asked for information on the general background of the farmer (to permit analysis of knowledge from different types of farmer), followed by five sections, each on subject matter from the original knowledge bases, namely: weeds, general soil fertility, inorganic fertiliser, animal manure and cover crops (Appendix III).

The questionnaire contained three broad types of questions about soil fertility management. The first type of question was open ended, in that the interviewer did not suggest any responses, but recorded key elements of the answer given. The survey form was designed to be filled in as quickly as possible, so expected responses, based on the original knowledge bases, were listed for each question. The interviewer was then able to tick those aspects articulated by the informant and add any other comments made by the farmer (Figure 4.1).

31) What is the soil of the black layer like?

Tick facts in answer

- ☐ it is soft (*emire*)
- ☐ water infiltrates well, there is little surface runoff
- ☐ water is retained well, the soil does not dry out quickly
- ☐ it provides plant food
- ☐ you find earthworms in it
- ☐ it makes the soil cool (*enyunu*)
- ☐ the soil is matured
- ☐ crops do well on it/give a high yield

Other

Figure 4.1 Example of an open-ended question

The second type of question was a multiple response or closed response question where potential responses were limited by the interviewer (Figure 4.2). These questions were used to test particular aspects of knowledge. They were used with elements of knowledge which were not commonly mentioned but which might still be general knowledge e.g. the influence of inorganic fertiliser on the palatability of vegetables, and with elements of knowledge which were unlikely to be known by everyone such as the selectiveness of a particular herbicide. Within this category were four questions asking for information that involved an element of subjective judgement rather than simply factual information such as whether *Chromolaena odorata* was an easy or a difficult weed to control.

25) Which of the following do you agree with:

Roundup kills all weeds – both grasses and broadleaved weeds
Roundup kills only broadleaved weeds
Roundup kills only grasses
Don't know (go to question 27)

Figure 4.2 Example of a multiple choice question

Finally, in addition to questions of knowledge, the survey also included questions about practice. For example, farmers were asked whether they had previous experience of using herbicide, fertiliser, manure and cover crops, and to name up to five of their most troublesome weeds. These questions were included in order to help interpret any differences in the distribution of knowledge encountered.

Although the majority of the questions in the survey were multiple choice (Table 4.7), open ended questions produced more individual responses as farmers often gave more than one response to these questions. In general, most knowledge was elicited using open ended questions as respondents cannot guess the answer as they can with multiple choice questions. The number of multiple choice questions in each section of the questionnaire was determined by the nature of the subject matter. The large number of questions in the weeds section is accounted for by specific questions about individual weed species, and the large number of questions in the general soil fertility section is accounted for by questions about land suitability for different crops.

Table 4.7 The number of questions of different types used in the knowledge distribution survey

Section of questionnaire	Type of question		
	Open ended knowledge	Multiple choice knowledge	Practice
Weeds	18	29	2
General soil fertility	7	45	0
Inorganic fertiliser	8	7	1
Animal manure	5	5	1
Cover crops	3	0	1
Total	41	88	5

4.1.6.2 Administration of the questionnaire

The questionnaire was administered under the supervision of the author by three Ghanaian enumerators, two male and one female. All three were, or had recently been university students of agriculture. It was not possible to use a female interviewer for all female informants. At the time of the interviews the gender of the interviewer did not appear to influence the responses given. Of greater importance was the ability of the interviewers to help the respondents to correctly interpret the questions (particularly where the respondents had had little education), the amount of prompting given to the informants to answer the open ended questions and the degree of interest and cooperation of the informants.

4.1.6.3 Survey location

The questionnaire was administered over five broad locations, which differed in their agro-ecology, level of tree cover, population density and market access (Table 4.8). The Asankrangua, Obuasi and Kumasi survey blocks had previously been characterised by the EPHTA[17] resource survey (Owusu-Akyaw, 1999). The Sunyani and Wenchi blocks were added to complete the knowledge distribution survey.

[17] The Ecoregional Program for the Humid and Sub-humid Tropics of Sub-Saharan Africa

Table 4.8 Characterisation of the blocks used in the local knowledge distribution survey

Survey block	Region	Agro-ecological zone	Level of tree cover	Population density	Market access
Asankrangua	Western	Evergreen forest	High	Low	Poor
Obuasi	Western and Ashanti	Moist semi-deciduous forest	Medium	Medium	Medium
Kumasi	Ashanti	Moist semi-deciduous forest	Low	High	Good
Sunyani	Brong Ahafo	Dry semi-deciduous (transition) forest	Medium	Medium	Medium
Wenchi	Brong Ahafo	Guinea savanna	Low	Low	Poor

Within each block, six villages were purposefully selected to ensure even spatial distribution and a contrast between high and low access to agricultural extension services (Table 4.9). Within the Asankrangua, Obuasi and Kumasi blocks these villages were chosen using data from the EPHTA survey (Owusu-Akyaw, 1999). In the Sunyani block three villages were selected where farmers were experimenting with soil fertility technologies as part of the Sedentary Farming Systems Project (Section 5.1) and three villages were selected where farmers were not participating. Least information was available about villages within the Wenchi block. These villages were selected based on their spatial distribution using a map. Data on access to extension services was then collected from these villages so that they could be classified in terms of extension access, resulting in four villages with high access and two with low access.

Table 4.9 Villages used for local knowledge distribution survey

Block	Region	Village access to extension services	
		High	Low
Asankrangua	Western	Nkonya	Ahyireso
Asankrangua	Western	Sikanti	Ankaase
Asankrangua	Western	Tigarekrom	Tweapease
Obuasi	Ashanti	9 Miles	Keniago
Obuasi	Ashanti	Akaasu	Kwamang
Obuasi	Western	Asawinso	Juabo
Kumasi	Ashanti	Abuontem	Koforidua
Kumasi	Ashanti	Asamang	Nimfuokrom
Kumasi	Ashanti	Bomfa	Tabere
Sunyani	Brong Ahafo	Kwaware	Kwasu
Sunyani	Brong Ahafo	Sereso	Monta
Sunyani	Brong Ahafo	Susuanso	Johnsonkrom
Wenchi	Brong Ahafo	Anyima	Nasana
Wenchi	Brong Ahafo	Menji	Sabiyi
Wenchi	Brong Ahafo	Menso	
Wenchi	Brong Ahafo	Subinso No.2	

In each zone the questionnaire was administered to 42 farmers, about seven farmers per village making a total of 210 farmers. Equal numbers of male and female farmers were interviewed from each zone using farmers randomly selected within each village.

Amongst the survey farmers cash cropping differed with location. Cassava and maize were important throughout. In the Wenchi block other important crops were yam, groundnut and vegetables, and in the Sunyani block plantain, yam and vegetables. In the Kumasi block plantain, cocoa and cocoyam were important. In the Obuasi and Asankrangua blocks cocoa, plantain, cocoyam and oil palm were important. (Table 4.10).

Table 4.10 Proportion of farmers growing different cash crops in the different blocks

Crop	Proportion of farmers (%)					
	Wenchi	**Sunyani**	**Kumasi**	**Obuasi**	**Asankrangua**	**All farmers**
Cassava	62	69	81	74	69	71
Maize	52	81	62	36	50	56
Plantain	10	48	67	55	62	48
Cocoa	2	7	29	55	60	30
Yam	64	24	10	7	2	21
Vegetables	33	24	10	14	12	19
Cocoyam	7	17	21	24	21	18
Groundnut	40	10	0	0	0	10
Oil palm	0	2	12	21	10	9
Rice	0	0	2	2	5	2
Citrus	0	0	5	2	0	1
Cowpea	2	0	0	2	2	1
Citrus	0	0	5	2	0	1
Other	14	5	0	0	0	4
Total	100	100	100	100	100	100

Two thirds of the farmers had no contact with the extension services throughout the year. As a result of the sampling method, individual farmers had significantly more access to extension services in the Wenchi and Sunyani blocks (Table 4.11). In the Sunyani block the villages with frequent access to extension were participating in a very active local agricultural development project run by an international development organization and, therefore, were likely to have received more extension visits than other villages with good access to extension. The villages selected in the Wenchi block were larger than those selected elsewhere and extension agents tend to reside in the larger settlements. In the other three blocks only 24% of farmers in total had any contact with the extension services.

Table 4.11 Individual farmer access to extension services at different locations

Frequency of contact with extension services	Proportion of farmers (%)					
	Wenchi	Sunyani	Kumasi	Obuasi	Asankrangua	Total
Never	45	39	79	93	71	66
Once or twice a year	33	22	7	2	17	16
3 - 5 times a year	14	15	12	2	10	11
6 – 10 times a year	5	12	0	2	2	4
More than 10 times	2	12	2	0	0	3
Total	100	100	100	100	100	100

Male farmers had significantly better access to extension than female farmers (Table 4.12). 45% of male farmers had some contact with the extension services whereas only 24% of female farmers had contact. Other characteristics of the surveyed farmer are given in Appendix IV.

Table 4.12 Male and female farmers' individual access to extension services

Frequency of contact with extension services	Proportion of farmers (%)	
	Male	Female
Never	55	76
Once or twice a year	17	16
3 – 5 times a year	15	6
6 - 10 times a year	7	1
More than 10 times	6	1
Total	100	100

4.1.6.4 Data analysis

The results of the survey were entered into a spreadsheet. These were then analysed using SPSS version 11. The Chi square test was used to determine whether there were any significant differences in responses given by different groups of farmers. Significant results were reported at the $p \leq 0.05$ level. If a group of respondents were significantly more likely to respond to a question, but in an inconsistent manner, rather than say 'don't know', this result was not reported as significant.

Knowledge questions were primarily analysed with respect to location (block), gender and access to extension services. Questions were evaluated with regard to both individual access to extension services, and village level access to the extension services. Differences were strongest when individual access to extension was evaluated, and it is these differences that are reported in the results. Knowledge questions were also analysed with respect to off-farm income generating activity, education, age, ethnic origin and cash crop type. Other factors that were included in the analysis of particular questions were previous use of inorganic fertiliser, animal manure, and cover crops.

4.2 Soil fertility management practices

The cropping and soil fertility management practices in the study locations are briefly outlined here to provide essential context for the local knowledge of soil fertility that is reported in Section 4.4. This overview is informed by observations and interviews at the five field sites with some comparison with secondary literature sources. A quantitative overview of the extent of these practices is given at the end of the section (Table 4.14) from a survey by Zimmermann (2001).

4.2.1 Bush fallowing

Soil fertility on farms in southern Ghana was largely maintained through the traditional practice of fallowing after the cultivation phase. During the final weeding, prior to the fallow, farmers refrained from cutting young saplings and sprouting tree stumps. Once weeding had stopped, crops such as cassava and plantain continued to be harvested whilst the fallow vegetation regenerated.

The vegetation succession on fallow land varied with location. At four of the five study sites, grasses and other herbaceous weeds were shaded out by *Chromolaena odorata* and other shrubs, which in turn were succeeded by trees. Trees shaded out the understorey vegetation leaving large vines and sparse undergrowth. These secondary forest fallows (known locally as *kwae* or *nfofoa kwae*) were becoming increasingly scarce due to the increase in population density resulting in shorter fallow periods. In many areas where cocoa was or had been an important crop, areas described as secondary forest fallows were in fact abandoned cocoa farms. Forest fallows were most common at Atwima, where they were usually abandoned cocoa farms, and at Oda where they were either abandoned cocoa farms, or else at some distance from the settlement. At Subriso they were less common, and they were very infrequently encountered in peri-urban Kumasi.

In the absence of secondary forest fallows, crops were grown on short fallow land cleared from grasses or *Chromolaena odorata*. Dense swathes of grasses, particularly *Panicum maximum* dominated on intensively cultivated land with very short fallow periods (from one season to two years). This type of fallow, known locally as *esre* was particularly common in peri-urban Kumasi and at Subriso on land that was close to the settlement, near to streams, or otherwise in short supply and moncropped with commercial vegetables, maize or cassava. Other shorter statured grass dominated in seasonally waterlogged valley bottom areas.

At the drier savanna site of Yabraso the natural vegetation was noticeably different from the other four sites. Farmers distinguished between two types of land: forest land dominated by *Chromolaena odorata* and other forest shrubs and trees, and guinea savanna woodland dominated by savanna trees and grasses (Section 3.4.3.2). In addition to *Panicum maximum* other grass species present included *Andropogonen spp.*, *Cenchrus ciliaris*, *Rottboellia cochinchinensis* and *Imperata cylindrica*.

Reports on agriculture, soil fertility and fallowing in the forest zone of Ghana typically state that fallow periods have declined leading to a reduction in soil fertility and crop yields (Amanor, 1993; Quansah *et al.*, 2001; Zimmermann, 2001). This effect is more pronounced in areas of higher population density close to large towns such as Kumasi (Asante *et al.*, 1999; Brook and Davila, 2000). At the field sites, farmers' opinions of recent trends in land use reflected these assertions in the literature. Furthermore, accompanying the decline in soil fertility due to reduced fallow periods, there was also a decrease in the length of the cropping period for some field types. Farmers commonly stated that whereas in the past they had maintained mixed food crop plots for three to four years, they now only maintained them for one or two years.

In addition to variation in the duration of the fallow period between field sites, there was also variation within individual locations. Differences in fallow duration were associated with differences in access to and distribution of land (Section 3.4.3.3) and the cultivation of different crops. Table 4.13 shows some estimates of ideal and actual fallow length given by farmers at the different field sites. Where bush fallowing was the only means of soil fertility management, actual fallows varied from two to ten or more years. Farmers considered that plantain required a longer fallow than other food crops such as maize and cassava, and that cocoa required an even longer fallow than plantain[18]. Below a minimum threshold, where farmers did not have sufficient land of their own to fallow, they tended to rent or sharecrop. Alternatively, they changed the crops grown. In the peri-urban Kumasi villages where pressure on land was highest, plantain was little grown, and was only found in backyard farm plots or at some distance from the settlement.

[18] Although it was not mentioned during the study, probably because of land pressure at the field sites, there may be an ideal maximum fallow for some crops. Amanor (1993) states that there is a maximum ideal fallow length for the most productive utilisation of labour. Farmers with surplus land in a degraded area of the Eastern Region considered three to six years to be ideal for food crops (i.e. not cocoa) as well developed forest requires a much greater investment of labour for tree clearing.

Table 4.13 Ideal and actual fallow lengths reported by farmers during local knowledge interviews at the five field sites

Location	Type of land/crops	Ideal fallow length	Actual fallow length
Gogoikrom*	Upland food crops	4 – 6 years	2 – 4 years
Gogoikrom*	Rice in valley bottoms	2 years	6 months – 2 years
Gogoikrom*	Cocoa	10 – 15 years	The longest fallows were abandoned cocoa farms
Peri-urban Kumasi	Upland food crops	6 – 10 years	2 – 4 years considered sufficient for maize and cassava, 4 – 6 years considered sufficient for plantain
Peri-urban Kumasi	Rice and dry season vegetables in valley bottoms	Moisture availability was more important than soil fertility, and fertilisers (mostly inorganic) were used.	2 months – 2 years
Oda	Cocoa	10 years or more	2 years – 40+ years: predominately 8 years +
Oda	Plantain	5 - 6 years	3 – 5 years
Oda	Maize, cassava and yam	5 years	3 – 5 years
Oda	Oil palm	Replanting could take place straight away after the felling of old trees.	-
Yabraso	Food crops on forest land	4 – 5 years	2 – 6 years
Yabraso	Food crops on grassland	5 – 6 years	3 – 10 years
Sunyani	Maize	3 - 5 years	Commonly 2 years, although variable depending on access to land

*Frost (2000)

Fallows were generally cleared with a cutlass. Vegetation was left to dry out for some time before being burnt. In some villages there were fire volunteer squads to supervise this operation. It was uncommon for farmers not to burn fallow vegetation. This only occurred when the vegetation had not sufficiently dried out before the start of the rains, when the farm was too close to another farm, particularly one growing cocoa, or very occasionally, when the farmer was using herbicide to clear a grass fallow (observed once in peri-urban Kumasi with a farmer who had been taught the technique by the extension services). Grasses forming dense tussocks such as *Panicum maximum* and *Pennisetum purpureum* were uprooted with a hoe or mattock and burnt thoroughly. Mounding and ridging were carried out for yam, groundnut and tomato. Other crops were planted without further land preparation[19]. Farmers were aware of differences in soil moisture and fertility in their fields and placed crops accordingly. Moist locations, such as around tree stumps oozing water, were sometimes used for vegetable

[19] Tractor ploughing is carried out in some areas of Brong Ahafo in the vicinity of state farms and other very large farms, but was not found at any of the field sites (Amanor, 1995).

nurseries and farmers often said that they planted plantain where there was a lot of rotting material (such as next to a fast rotting tree branch).

Farmers removed the majority of trees on their farms, particularly when cultivating light demanding crops such as maize and vegetables, less so for plantain, which benefits from shelter from wind provided by trees. On cocoa farms, farmers were retaining fewer shade trees for the less shade tolerant modern hybrid cocoa variety than for the older *amazonia* and *amelando* varieties. Trees were removed by felling with a chainsaw prior to burning, by repeatedly setting light to them, or by ring barking.

Farmers linked changes in fallow vegetation to changes in weed ecology and weeds were identified as significant farm problems at all the field sites. Farmers claimed that where they formerly had to weed once or twice during the growing season, they now had to weed two or three times. Weeds sometimes appeared to be more significant problems to female farmers, for example at Oda and Atwima (Frost, 2000; Moss, 2001b), possibly because the gender division of labour in cocoa growing areas meant they were more involved in weeding, but also possibly because women's domestic duties hampered their farm management. Common weed species and farmers' knowledge of them can be found in Section 4.4.3.3. Amanor (1995) has linked the commercialisation of agriculture in transitional areas of Ghana with the invasion of grassy weeds. He states that grass weeds have spread from the savanna areas along roads and paths and into cleared farm plots, encouraging bush fires in the dry season which prevent the build up of organic matter.

Weed management for most crops involved slashing weeds at the roots or base of the stem with a cutlass and spreading them on the ground. Groundnut was weeded by hand, that is, without a cutlass, and this was considered tedious and time consuming and was carried out by women. Earthing up was carried out with a hoe for other crops such as tomatoes grown on mounds or ridges. Use of herbicide was not common, but appeared to be more frequent in peri-urban Kumasi and the cocoa growing areas than in the Brong Ahafo region. Farmers sometimes diluted the herbicide solution with ammonium sulphate or salt.

4.2.2 Other practices

The regular use of inorganic fertiliser was primarily restricted to commercial vegetable growers and some rice farmers. Tomatoes, garden egg and exotic vegetables such as cabbage, carrot and sweet pepper commonly received inorganic fertiliser, but it was less common for okra and chilli pepper. Sulphate of ammonia was sometimes broadcast on rice when leaves

were yellow. Extension agents in some areas including peri-urban Kumasi have encouraged the use of fertiliser on plantain, but interviews with farmers revealed that this had only been done on an experimental basis involving irregular use on a few plants. Fertiliser was also sometimes used on young oil palm plantations to reduce the time to first fruiting. Zimmermann (2001) also reports the use of fertiliser on maize cash crops grown in valley bottoms on residual soil moisture. For the most part farmers applied fertiliser as a side dressing. They used whatever type of fertiliser was available, which at the time of the study was 15:15:15 NPK compound fertiliser, or less commonly sulphate of ammonia. In the dry season they dissolved it in water before applying it to vegetables.

Livestock keeping was generally considered a separate activity to crop cultivation and there was little integration of crop and livestock farming. Furthermore livestock numbers were low outside peri-urban areas. Some farmers said they had occasionally used animal manure from their own animals on backyard farm plots (particularly on plantain). The use of animal manure on a larger scale than this appeared to be restricted to vegetable farmers in peri-urban areas who were able to transport it from intensive poultry units in their vicinity. These farmers used it as a substitute or supplement for inorganic fertiliser. A number of farmers mentioned the use of animal manure in solution as an insect repellent and animal deterrent on the leaves of crops. Household refuse, particularly plantain and cassava peelings were fed to goats and sheep where these were kept, and occasionally placed on backyard farm plots although this practice was actually banned by the village at Oda as it was considered dirty. For the most part, household refuse and animal droppings were taken to the village refuse heap.

Despite over ten years of research on leguminous cover crops, legumes with limited food value such as mucuna and canavalia were not found at the five study sites and their use appeared to be restricted to the limited number of farmers reached through specific projects and field trials. Pueraria is used under oil palm in Ghana, but was not found at any of the study sites and is confined to large oil palm estates and out-grower schemes rather than amongst smallholder farmers more widely. A few farmers at Oda and peri-urban Kumasi said they had been encouraged to grow sweet potato as a form of cover crop by extension agents.

These observations of farmers' soil fertility management practices were consistent with previous surveys such as Asante *et al.* (1999). Zimmermann (2001) did a quantitative survey of farmers' soil fertility management practices in the Kumasi, Obuasi and Asankrangua blocks and her figures give a quantitative overview of the extent of soil fertility practices (Table 4.14). One fifth of fields received inorganic fertiliser in Zimmermann's (2001) survey compared to 5.8% of plots or 9% of farmers from six villages surveyed in the Brong Ahafo

region by Amanor *et al.* (2002). Zimmermann (2001) found that only 4% of fields received animal manure from village animals. In the peri-urban villages 6% of fields received poultry manure (sourced from an intensive poultry unit). Use of cover crops and green manures was too seldom to include in the figures. No farmers made use of the 'black soil' from the refuse dump considering it unhygienic and malodorous. Nevertheless, the local knowledge research reported in this chapter found that farmers were aware of and valued for cultivation the higher fertility of areas that were once used as village refuse dumps, but this was only after some years had passed.

Table 4.14 Farmers' soil fertility management practices in fields of the Kumasi, Obuasi and Asankrangua blocks

Practice	Percentage of fields applied to (n=612)
Bush fallow practices:	
Burning fallow vegetation	98
Preservation of trees	52
Special placement of crops (especially yam, plantain and vegetables)	58
Leaving all weeds on the soil surface	81
Placing weeds directly next to crops	12
Leaving crop residues on the ground	74
Placing crop residues directly next to crops	2
Other:	
Use of inorganic fertiliser	20
Use of manure from own animals	4
Use of household refuse	4
Use of black soil or compost from the village refuse heap	0

Source: Zimmermann (2001)

4.3 Farmers' sources of agricultural information

In addition to their own observation and experimentation, farmers obtained information about agriculture from a diversity of sources originating both within the village and at some distance from it. Questions on farmers' sources of agricultural information were included in interviews with farmers in peri-urban Kumasi and at Oda. The most frequently mentioned sources of information were other farmers, radio programmes and the extension services. When asked what they did when they had a problem, many farmers either mentioned going to other farmers for advice, or else to the extension services, although it is unlikely that this is in fact a frequent occurrence – two thirds of farmers interviewed during the knowledge distribution survey saw an extension agent less than once a year. Other farmers said they relied on themselves to solve their own problems. The proportion of farmers using different sources of information is not provided in the following sections. Although the interview responses were informative, around three quarters of the farmers interviewed were either from a village where there was a very visible agricultural project with multiple technical staff, or else farmers

interviewed had been directly participating in a project providing agricultural information to farmers.

4.3.1 MOFA extension services

The extension services of the Ministry of Food and Agriculture (MOFA) were responsible for agricultural extension to farmers. The Cocoa Services Division (CSD) had formally provided cocoa and coffee extension but their services were subsumed under MOFA at the end of 2000 (MOFA, 2001). At Oda a community agroforestry project was a potential source of information on agroforestry, crop rotation, use of compost, manure and fertiliser, snail farming, bee keeping and fishponds.

Extension agents for two of the study sites were interviewed in some depth. In addition to this, semi-structured interviews were held with 17 MOFA extension agents responsible for the villages within the Kumasi, Sunyani and Wenchi blocks of the generalisation survey, about the soil fertility management technologies that they had been teaching. Five of these were women and twelve were men. Four resided in the villages visited during the survey, twelve resided elsewhere, and one split his time between the village and the district capital. The majority of extension agents and the extension officers who were supposed to supervise them resided in the larger settlements due to the better facilities (such as electricity and piped water), which sometimes resulted in low levels of supervision of extension agents working in remote areas. Extension services varied between villages, with some villages visited by MOFA personnel on a regular basis and others receiving very few visits or only intermittent services. In the Asankrangua district extension agents were available for only 19 operational areas out of a total of 38 at the time of the research. The Atwima district development plan reports that 13 out of the 15 operational areas had extension agents and in consideration of the large size of the district the ratio of farmers to extension agents of 11747: 1 was particularly high, compared to the national average of 1:3000 (Government of Ghana 1996b).

Visits by extension agents often seemed too infrequent to inspire farmers' confidence. Extension agents gave a number of reasons for not visiting communities. The finance they received for transport to villages was insufficient so that locations within walking distance of their homes were likely to be visited more often than those further away. Their places of residence were not always convenient for visiting the farming areas they were responsible for. In some locations the extension agent was not made welcome in the village. There was one example where the agent had delivered a maize package, where the seed given was intended

to be repaid in cash form at harvest time. However the farmers did not want to repay and so did not make the extension agent feel welcome anymore and he stopped visiting.

Extension messages delivered to farmers at Subriso included improved maize varieties, maize storage, lining and pegging for row planting, the mixing and spraying of agrochemicals, early weeding, farm record keeping and inorganic fertiliser use. Advice from the Cocoa Services Division technical assistant at Oda centred around weeding, spraying of pesticides and the removal of undesirable shade trees. The CSD did not generally recommend any soil fertility practices to farmers although the technical assistant suggested low soil fertility as one of the reasons for the low cocoa yields obtained by farmers. Generally speaking, extension messages only appeared to focus on soil fertility management when extension agents were involved in externally funded projects, or on request from the farmers themselves. However the majority of extension agents clearly had technical knowledge of the use of inorganic fertiliser, manure, composting, legumes and herbicide. They did not always pass on this knowledge to farmers because they did not consider it appropriate to farmers' circumstances, or because farmers showed no interest in their advice. For example, many claimed that vegetable farmers experimented with their own methods and quantities of fertiliser application. In some areas there was little animal manure available and many extension agents had been trained in compost preparation but thought that farmers would consider these methods too laborious. For specialised technologies such as herbicide use, extension agents offered advice to individual farmers who were interested. Extension agents were always mindful of their own social position and that they needed the cooperation of the farmers in order to carry out their duties.

Contact between the extension services and farmers took a number of forms. MOFA operated the Training and Visit model, using groups of around ten contact farmers with whom extension agents had greatest contact. Extension agents used group training and demonstration sessions to try to reach as many farmers as possible. They were often also responsible for carrying out trials with farmers or delivering technology packages which were being implemented by another agency in conjunction with MOFA. These included the outreach trials of the Crop Research Institute, collaboration with agricultural research and development projects financed by overseas agencies and HIV awareness raising programmes. Finally, some farmers would seek out the extension agent and ask for specific advice and attempt to arrange a farm visit when they had a problem on their farm or when they wanted to try a new technology for the first time such as the application of the herbicide 'Roundup' (glyphosate). If they could not get hold of the extension agent in the village they would call at their house in town or the district office.

Farmers clearly appreciated farm visits and put more trust in the extension services when their advice was based on a farm visit. However they reported that it was not always easy to get the extension agent to visit their farm as they preferred to reach as large an audience as possible through group teaching. Other farmers said that they had to give the extension agent something for making the visit such as money for transport or some farm produce. Extension personnel expressed frustration that group trainings were poorly attended and farmers did not take up the practices they recommended, saying that farmers were conservative and preferred to learn from one another than from the extension services.

4.3.2 Other sources of information

Fellow farmers and family members were important sources of knowledge. Parents and grandparents were often attributed with teaching people how to farm and some farmers still turned to these people for advice when they had a problem. Observing the activities of other farmers, and talking with them was particularly important for specialised farmers such as commercial vegetable and rice growers. However, farmers with other food crops would also observe what market orientated farmers were doing and sometimes try practices out on their own crops, such as one lady who tried poultry manure on her plantain. Sometimes one or more of the larger innovative farmers were particularly well known in the village and sought after for agricultural advice.

Agro-input retailers gave advice on pest and disease management, and were therefore consulted more by vegetable farmers. Many people listened to radios and mentioned farmers' programmes as well as advertisements for agro-chemicals. There were also sometimes television programmes about specialist subjects such as snail keeping although only one or two people mentioned these. Some farmers had contacts within the larger agricultural sector which they clearly valued and to whom they turned for advice and training on specific issues, such as how to graft fruit trees. These contacts included a cocoa buyer and workers on large farms, plantations and research stations. A few of the more educated farmers mentioned Senior Secondary School where they had attended agricultural classes and some cocoa farmers mentioned written extension materials that they had consulted.

Overall, men tended to have more contact with information sources located or originating outside of the village. They were more likely than women to visit the district agriculture office, to purchase agro-chemicals, and to have contacts within the formal agriculture sector. They also attended group training sessions more than women. Women were more likely to

visit an extension agent resident in the village and to go to other farmers for advice than to seek information from agricultural offices or agro-input retailers outside the village. Some women claimed not to have time to attend group training sessions but to rely on their men folk to pass on the relevant information. These findings agreed with those of Carter (1999) for various farmers' groups throughout the whole of Ghana, although NGOs played a greater role in information provision in Carter's study, probably as farmers' groups are often formed through association with NGOs. The findings also agreed with Gerken *et al.* (2001) who looked at information sources for pesticides and Arokoyo (1998). Gerken *et al.* (2001) also found that larger farms used more sources of information than smaller farms, and that the higher a farmer's education level, the more he depended on a greater variety of information sources.

4.4 Local knowledge of soil fertility

Farmers' knowledge of soil fertility management is presented in the following sections. Farmers' concepts of soil fertility are explained first. This is followed by an account of how farmers' recognize different types of soil. After this, farmers' knowledge about the main means of managing soil fertility – the use of fallows, is presented. Farmers' knowledge of the integration of trees into cropping patterns, inorganic fertiliser and animal manure then follows. The detailed qualitative understanding of farmers' knowledge presented here is the result of the creation and evaluation of formal knowledge bases at the five field sites (Section 4.1.3). The quantitative data shown are derived from the knowledge distribution survey (Section 4.1.6).

4.4.1 Fertile soil

Farmers used a number of different terms to refer to land and soil and changes in soil fertility (Table 4.15). *Ahoōden* which means strength in *Twi*, was the most commonly used adjective to describe fertile soil. Farmers with more schooling or exposure to the extension services were able to talk of soil that had *seradeē*, fat, or *aduane*, 'contained food'. These concepts were used in school and by agricultural extension agents to refer to plant nutrients. *Asaase ōkyene adeē* ('land that helps things') was the most common way for farmers to refer to fertile soil at Oda, but was not used elsewhere. Farmers associated cool (*nwunu*) soil with soil that had moisture in it, and cool soil was also associated with good crop growth and even the use of fertiliser. In contrast, *asaase shesheshe* or hot soil was associated with infertile soil.

Table 4.15 Terminology for fertile and infertile soil

Terminology (Twi)	Literal meaning	Explanation
Ahoōden	Strength/power	Fertility
Seradeē	Fat	Fertility
Aduane	Food	Soil nutrients
Asaase ōkyene adeē	Land that helps things	Land that is good for crop growth/fertile soil (used only at Oda)
Asaase a enyine	Land that is mature or well grown	Fertile soil found after a long fallow
Asaase shesheshe	Hot land	Characteristic of infertile soil
Enyunu	Cool	Characteristic of fertile soil

Careful questioning of farmers revealed an aggregate concept of soil fertility. Fertile soil was equivalent to 'land that crops do well on', and more particularly land that was able to provide plants with moisture and nutrients. Farmers recognised that fertile soil had a high organic matter content derived from the decomposition of large quantities of vegetation. It was described as being cool, and remaining so when the sun was shining on it. It was soft and friable and a cutlass went into it easily and deep. It produced fewer weeds during the cropping phase and required weeding only once or twice. Conversely, infertile soil had low organic matter content, was hard or compact, produced different weed flora to fertile soil and these weeds tended to be invasive and difficult to control. It produced stunted plant growth with low yields.

Farmers perceived a strong association between fertility and organic matter (Section 4.4.3.1), and the properties associated with fertile soil were similar to those associated with organic matter (Table 4.16). Organic matter was said to give crops the strength to grow, and to improve the physical properties of the soil – improving the infiltration and retention of rainwater, decreasing surface runoff and making the land easier to cultivate.

Table 4.16 Distribution of knowledge about the properties of organic matter

Property of organic matter	Proportion of farmers mentioning property (%, n=209)
Produces good crop growth or yields	82.3
Is soft	75.6
Is cool	58.4
Presence of earthworms	25.4
Black in colour	21.5
Good water retention	19.6
Found after a long fallow	18.2
Provides plant nutrients	13.9
Good water infiltration	7.7

Farmers' soil knowledge was to some extent contextualised. Farmers often had a particular crop in mind when discussing fertility. There were areas at Oda that were known from experience to be suitable for food crops but not for cocoa. Good land for rice at Gogoikrom was not the same as good land for cocoa. In fact, seasonally waterlogged valley bottoms

where only rice could be grown in the wet season was not valued by all farmers. Farmers with no interest in rice or dry season cultivation might express no ecological knowledge about these soils at all, and consider them simply unsuitable for cultivation. Some, usually the best, land or soil was said to be good for all crops, that is, all upland food and tree crops that farmers commonly grew. Other soils were considered suitable only for specific crops. Soil fertility was, therefore, always a relative concept, and the choice of crop was one means, usually the primary one, of managing it.

Farmers used crop yield and plant growth as the major indicators of soil fertility (Table 4.17). The vegetation on fallow land was used to judge whether the land was suitable to clear and cultivate, although the duration of the fallow also gave some indication. Soil was also evaluated through sight and touch. Fertile soil suitable for cultivation would be black, friable, moist and might contain earthworm castes indicating a high organic matter content, although, as already stated, the requirements for different crops varied.

Table 4.17 Farmers' indicators of soil fertility and infertility

Indicator	Fertile soil	Infertile soil
Crop yield	High with large fruits and tubers	Low with small fruits or tubers
Crop growth	Good, e.g. *fēfēfē* (beautiful) with dark green (*tuntum**) leaves	Stunted crops with yellow leaves (especially rice), lodging of plantain in the dry season, and high weed competition with the invasion of grassy weeds on crop land.
Secondary forest fallow	Present with large trees, little undergrowth that was easy to pass through, thick creepers and vines.	Not present
Chromolaena odorata dominated fallow	A few thick stems and plant bases of *C. odorata* with large green leaves and few grasses	Many *C. odorata* plants with thin stems and small yellow leaves and some grassy weeds. Stunted plant growth.
Grass dominated fallow	Not present	Present
Fallow duration	Variable and dependant on the crop to be grown – 6 to 10 years sufficient for most crops	Shorter duration than desired for high fertility
Soil characteristics	Black surface colour, soft, cool and moist with earthworm castes present.	Hard or with termites present.

* *Lit.* black

4.4.2 Spatial differences in land and soil

4.4.2.1 Soil types

There was much similarity between the five field sites in the ways that farmers referred to and distinguished between different types of land and soil. Topographic position, colour, texture and stoniness were the main features used. Five common soil types emerged (Table 4.18).

Table 4.18 Soil types described by farmers

Local name	Other local names	Meaning of name	Topographic position	Colour*	Texture and consistency	Moisture availability
Asaase kōkōō	*Nōteē kōkōō, sibini*	Red soil	Upland and lowland	Red	Frequently sticky, sometimes stony	Water infiltration can be slow but retention is high
Asaase tuntum	*Nōteē tuntum*	Black soil	Sloping land and lowland	Dark	Loamy	Water infiltrates well, and retention is high
Afonwea	*Anwea, anwea asaase*	Sandy soil	Lowland, above ateche	Usually dark or light	Sandy or alluvial	Rapid infiltration and drainage.
Ateche	*Petra, afroo asaase, asaase fufuo*	Clay soil	Valley bottoms	Dark or light	Clayey or muddy and seasonally waterlogged	Waterlogged in the wet season
Abosia	*Abontem*	Stony or gravely soil	Any, but commonly upland	Any, but commonly red	Stony or gravely	Water infiltration can be slow but drainage is more rapid than other upland soils

*colour terms used by the farmers are relative terms and hence sometimes debatable e.g. whether a greyish soil is described as white or black.

By far the most common upland soil type was *asaase kōkōō* (red soil) which was present in every village. Farmers usually described a heavy soil with a high clay content that was sticky and slippery when wet, and might crack in the dry season. *Abosia* (stony or gravely soil) was mentioned as a specific soil type in some locations, although in others farmers were aware of gravel content but did not specifically refer to a particular soil type. *Abosia* might occur anywhere in the landscape on soil of any colour, but it was most likely to be found on upland and to be similar to red soil but with more gravel.

Soil described as *tuntum*, or dark in colour, was recognised as having a high organic matter content and could be found anywhere in the landscape. It was usually considered to be the most fertile soil, and was described as loamy with good moisture infiltration and retention. At peri-urban Kumasi *asaase tuntum* was associated with old village refuse tips and at Gogoikrom with secondary forest. Some farmers recognised that black soil had a dark topsoil but might be underlain by a red soil. In other locations farmers used *asaase tuntum* or *afonwea tuntum* to refer to lowland soils that were darker in colour than other lowland soils of a similar texture or consistency. Again the darker soil was considered more fertile.

Where seasonally waterlogged valley bottom areas existed farmers distinguished a heavy clay soil that they variously termed *ateche, petra, afroo asaase* or *asaase fufuo*. As valley bottom areas were not found in all locations this soil was not common to all villages. Although termed *asaase fufuo*, or white soil in some locations, the actual colour of this soil varied from dark to light in colour.

Lowland soils were generally light or dark in colour, and much less frequently red. In all areas farmers distinguished a loose soil with rapid drainage known as *afonwea* (sandy soil) also sometimes referred to as *anwea* - *lit.* sand), and found next to water courses. Farmers often distinguished between lighter and darker variants of this soil as already discussed. In some locations such as at Oda, there were large flat lowland areas with a light coloured soil that was muddy when wet and hard when dry. This was often referred to as *asaase fufuo* (white soil), and again farmers distinguished between lighter and darker variants.

Overall, farmers did not appear to use a consistent naming system for soil types although they were clearly aware of the different properties of soil in different locations and how these clustered together. Their use of terminology to refer to similar soil types was not consistent, either amongst sites or amongst people within the same village. Furthermore soils with different properties might be referred to with the same name e.g. *asaase fitaa* (white soil) might be used for either a sandy soil (*afonwea*) or a clayey soil (*ateche*). When asked a more specific question, such as the best soil for cocoa at Oda, they replied variously by naming specific locations (e.g. toward Bomadin), referring to vegetation (e.g. secondary forest), or naming soil properties (e.g. loaminess).

Furthermore, the knowledge of individual farmers varied. Many farmers were only willing to talk about soils that they had experience of cultivating which might only be one type if their cultivated parcels were located in the same place. Detailed discussion with individual farmers about the properties of different soils revealed that there were different types of soil within the broad categories mentioned in Table 4.18. For example, at Oda farmers referred to loose and muddy types of white soil, loose and elastic types of red and black soil, and red soil with a black subsoil.

4.4.2.2 Soil properties

Farmers' more detailed descriptions of different soils commonly included year round moisture availability and suitability for different crops in addition to colour, location, texture and consistency. They mentioned gravel where present but only depth when prompted or where it was a limiting factor such as in association with cocoa at Oda. Across the locations farmers' soil descriptions were broadly similar. Detailed descriptions of soils at the each study site can be found in Frost (2000), Obiri-Darko *et al.* (2000), and Moss (2001a; 2001b).

Farmers took all these properties into account when considering site suitability for different crops. Moisture availability was particularly important, and frequently mentioned. In lowland

and valley bottom areas the water table influences moisture levels whereas on lowland and upland texture and structure were important. Finding soils with the right balance of year round moisture availability was most frequently mentioned in relation to plantain and cocoyam. Texture and consistency are also limiting factors for root crops, particularly cassava and cocoyam. Farmers preferred loose or well drained soil for these crops including sandy and stony soil.

Laboratory analysis of soil samples

Soil samples were taken for laboratory analysis from four villages in the Brong Ahafo region using methods described in Section 4.1.5. The soil types identified by the farmers were those listed in Table 4.18 except that only three soil types were identified at Monta, four at Johnsonkrom and all five at Sereso and Susuanso. Farmers' assessments of the properties of the soils sampled were elicited during group interviews. The results of the laboratory analysis are given in Appendix V.

Laboratory analysis revealed that soils from Susuanso had the lowest organic matter and phosphorus and potassium, whereas Monta had the highest levels. At Johnsonkrom phosphorus levels were similarly low to Susuanso. Available nitrogen was less consistent. Inorganic fertiliser had been applied the previous year on the sandy soil at Johnsonkrom and on the sandy, red and stoney soils at Susuanso. There had been no fertiliser or manure applied on any of the other soils in the past year. Interestingly, Susuanso was the largest and most accessible village (with a population estimated at 3000), whereas the population was very small at the other three sites (300 or less). Monta was the smallest and least accessible settlement, being at the end of a side road. Johnsonkrom and Sereso were also both small, but despite being very rural appeared to have better connections to larger nearby settlements.

The sandy soils at each site generally had the lowest water holding capacity, followed by the stony soils, whereas the clay soils had the highest. An exception occurred at Susuanso where the black soil had a particularly heavy texture. Organic matter levels were low at Susuanso and in the sandy soils, but medium elsewhere. Phosphorus was very low except on red and black soils at Sereso and Monta. Potassium levels were low at Susuanso but moderate elsewhere. There were significant correlations between organic matter and available nitrogen, water holding capacity, potassium and phosphate (Table 4.19).

Table 4.19 Linear correlations between organic matter and other soil properties

Soil property	Pearson Correlation Coefficient	P	
Water holding capacity	0.7018	0.000	***
Available N	0.4246	0.000	***
Phosphate	0.2319	0.030	*
K	0.3513	0.001	***
pH	0.0805	0.453	
EC	0.4507	0.000	***
% rocks	-0.0634	0.555	

*** $p \leq 0.001$
** $p \leq 0.01$
* $p \leq 0.05$

Comparing farmers' knowledge with the laboratory analysis

At first glance, a comparison of farmers' ranking of soil moisture availability and measured water holding capacity did not show any close correspondence (Table 4.20). The sandy soils were almost consistently the lowest in terms of water holding capacity, although farmers in three of the four locations ranked them very highly. This was because some sandy soils did not dry out despite rapid drainage due to sub-surface properties and farmers' evaluations of moisture availability took into account both soil location and texture. Once this aspect of farmers' ranking had been taken into account, their ranking followed the values for water holding capacity at Sereso, Susuanso and Monta. Only farmers' ranking of red soil at Johnsonkrom did not follow the laboratory values for water holding capacity. Farmers' evaluation of moisture availability was, therefore, contextualised, accounting for location as well as texture, and incompletely predicted by laboratory measurement of water holding capacity.

Table 4.20 Comparison of farmer ranking of soil moisture availability and analysis of water holding capacity

Soil type	Johnsonkrom		Monta		Sereso		Susuanso	
	F*	WHC (%)*	F	WHC (%)	F	WHC (%)	F	WHC (%)
Black soil	1	46.8	-	-	4	42.6	1	52.1
Red soil	4	46.6	3	54.2	3#	42.9	3	36.3
Clay soil	-	-	1	64.4	1	50.3	2	40.9
Stony soil	3	36.8	-	-	5	38.7	5	31.8
Sandy soil	1	33.6	1	38.0	2	33.3	4	36.3

*F indicates farmers' ranking, WHC is mean water holding capacity.
Farmers at Sereso differentiated between red soils depending on topographical position: lowland soils have good moisture availability but those higher up do not.

No single soil parameter measured explained farmers' ranking of fertility, however farmers' did appear to rank soils according to utility and productivity (Table 4.21). Clay soils were ranked lowest at two out of three sites, despite nutrient levels comparable with other soil types, as farmers saw these soils as of utility for only a few specialised crops. These soils were nevertheless used at all the sites for cash crop cultivation.

Black soils were ranked the highest by farmers, followed by sandy soils at those locations where sandy soils were also ranked highly for moisture availability. As farmers associate black soil with high organic matter, this suggests that their evaluation of productivity was based on organic matter and moisture availability.

Despite farmers' association of dark soil colour with organic matter, in the laboratory analysis black soils did not have the highest levels of organic matter, as texture was more important in this respect. Lighter soils were associated with low organic matter and low water holding capacity whereas heavier soils were associated with higher organic matter and water holding capacity. Farmers may have found that productivity is higher on sandy soils with sub-surface moisture supply, and loamy soils, rather than heavier upland soils under conditions of unreliable or insufficient rainfall. In the knowledge base for Subriso, farmers had stated that red soils could be more productive than black soils when rainfall was high.

Table 4.21 Comparison of farmer ranking of fertility and chemical analysis

Soil type	Johnsonkrom*						Monta*						Sereso*						Susuanso*					
	F	**C**	**N**	**P**	**K**	**pH**	**F**	**C**	**N**	**P**	**K**	**pH**	**F**	**C**	**N**	**P**	**K**	**pH**	**F**	**C**	**N**	**P**	**K**	**pH**
Black soil	**1**	4.6	11.0	12.3	26.3	6.36	-	-	-	-	-	-	**1**	4.8	8.2	9.7	110.9	7.86	**1**	4.6	12.3	3.0	25.5	6.10
Red soil	**4**	9.8	15.9	4.0	199.0	7.03	**3**	10.7	28.7	4.9	293.1	6.62	**3**	6.1	8.0	3.2	88.6	7.27	**2**	4.3	8.0	3.0	53.1	6.08
Clay soil	-	-		-	-	-	**2**	7.5	10.6	27.2	14.6	6.25	**5**	5.8	7.0	18.1	125.2	7.71	**5**	3.1	4.4	4.15	35.7	6.69
Stony soil	**3**	6.4	22.0	2.5	114.5	5.87	-	-	-	-	-	-	**4**	6.7	4.9	2.8	72.5	6.91	**4**	4.6	5.3	2.5	13.5	6.57
Sandy soil	**2**	2.5	12.5	3.1	53.2	6.80	**1**	3.7	15.9	39.7	476.2	7.54	**2**	3.1	17.2	4.1	129.0	6.49	**3**	3.0	18.1	4.1	22.8	6.34

*F indicates farmers' ranking of soil fertility. Other values are mean values for C, % organic matter; N, available nitrogen (mg kg^{-1}); P, phosphorus (mg kg^{-1}) and K, potassium (mg kg^{-1}). At Johnsonkrom only the 0 – 15 cm layer was sampled, whereas elsewhere means refer to 0 – 15 cm and 15 – 30 cm soil layer samples.

4.4.3 Bush fallowing

Fallowing was the main means of managing soil fertility. Farmers recognised that fallowing served two main functions – it enabled the accumulation of soil organic matter and it led to a change in weed flora through vegetation succession.

4.4.3.1 Organic matter accumulation

All farmers were able to describe how fallowing results in the build up of organic matter. Large quantities of decomposing vegetative biomass mix into the soil and make it soft and black. Farmers recognised that the type of land or soil had an influence on vegetative growth and organic matter accumulation. They associated trees with the production of large quantities of leaf litter and woody biomass. At Yabraso farmers said that organic matter accumulation took longer on guinea savanna woodland than on forest land as grasses dominate and annual bush fires occur. At Oda land that had been used for surface gold mining (*galamsie*) was said to take as long as 20 years or more to regain its fertility. At Atwima farmers stated that organic matter accumulation was slower on lowland sandy soils than on red or black upland soils.

As already stated (Section 4.4.1), farmers considered soil fertility in relation to particular crops. Similarly, farmers considered organic matter accumulation when judging soil suitability for different crops. Well grown secondary forest fallows which had been left for 10 years or more permitting a high soil organic matter accumulation were preferred for the cultivation of cocoa. Food crops were grown on land with shorter fallows. Five or six years was considered adequate for plantain, two to five years for maize and cassava and a similar amount of time for yam in the forest and transition zones. Oil palm could be felled for palm wine and land then replanted immediately. Groundnut and cowpea were said to yield on any soil, even if low in organic matter.

Soil fertility and organic matter accumulation also influenced how long the land could be cultivated before it was fallowed again. For instance, at Atwima, farmers claimed that on red soil (*asaase kokoo*), a fallow of five years might be followed by a cultivation phase of two years, and a fallow of eight to ten years might be followed by a cultivation phase of four to five years. This was particularly significant for plantain, as farmers might attempt to farm plantain on the same land for up to ten years. At Subriso maize might yield well for two consecutive years if the original soil fertility was high and at Oda cassava might be replanted three consecutive times.

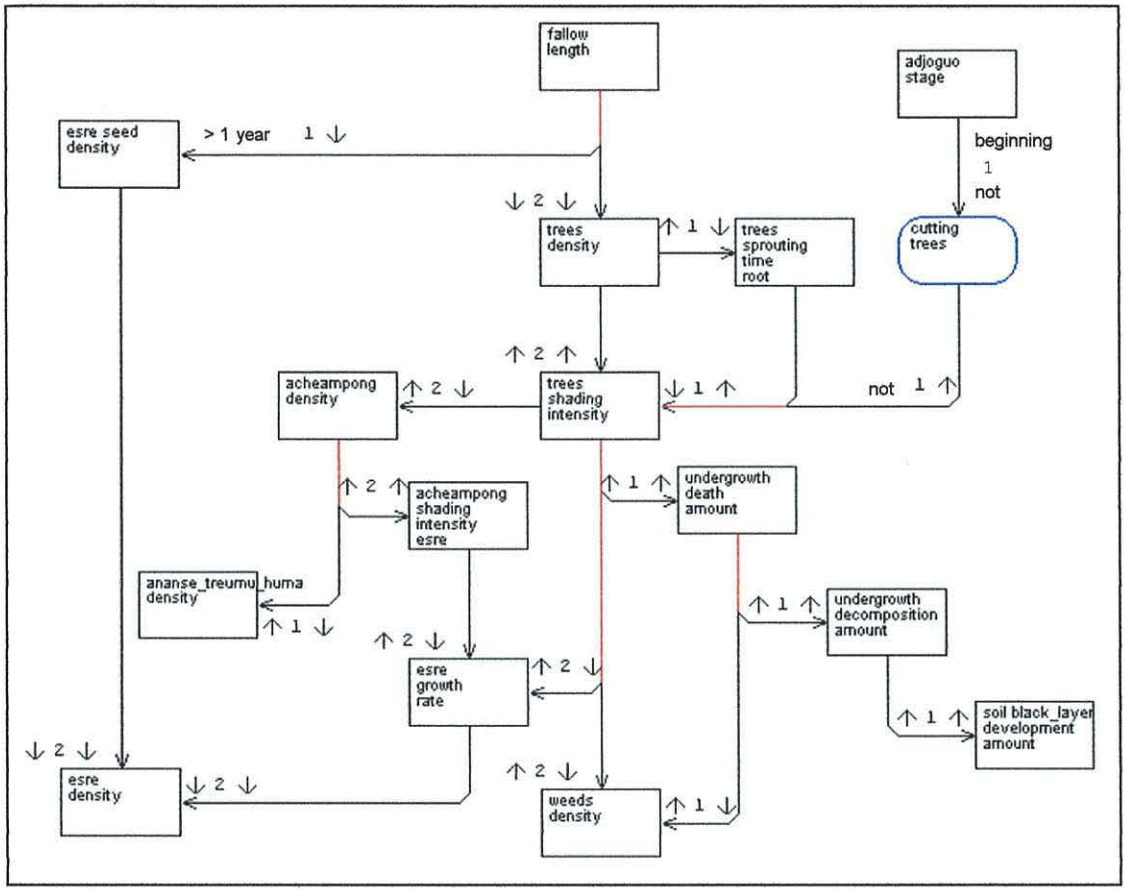
4.4.3.2 Fallow vegetation

Farmers understood well the succession of vegetation on the fallow. They had different ways of referring to fallows at different stages of vegetation succession (Table 4.22). Farmers were able to describe how trees and shrubs on the fallow formed a canopy and shaded out the weeds which appeared during cropping.

Table 4.22 Terminology used to refer to fallowing

Terminology	Explanation
Begya asaase no atoho	Fallow (*lit.* to leave the soil and put it down).
Nfofon bi anyini	The fallow is mature or well grown.
Adjoguo	The start of the fallow, when weeding has stopped but plantain and cassava continue to be harvested.
Nfofo	May refer to a fallow of any age. Frequently used to refer to a shrubby fallow dominated by *acheampong* (*Chromolaena odorata*).
Kwae	Forest, i.e. land dominated by trees with little undergrowth.
Nfofo kwae	Secondary forest, land with a mixture of trees and understorey shrubs.

Figure 4.3 is a diagrammatic representation of farmers' knowledge of vegetation succession on the fallow at Gogoikrom. At the start of the fallow (*adjoguo*), farmers continued to harvest plantain and cassava, but ceased weeding. Sprouting tree roots and stumps accelerated tree growth. *Chromolaena odorata* (*acheampong*) shaded out grasses (*esre*) and other weeds, including *Centrosema spp.* (*ananse treuma huma*) a common weed at this location. The seeds of *esre* survived for less than a year. *C. odorata* and other undergrowth was then shaded out by trees. Decomposition of this undergrowth formed a 'black layer' on the surface of the soil, which was the soil organic matter that farmers valued.



Two nodes with an arrow between them represent one causal knowledge statement. The statement should always be read in the direction of the arrow. Each statement has a pair of values associated with it which are the symbols, letters and words outside of the nodes. These values should always be read from left to right. ↑ indicates an increase, ↓ indicates a decrease. 2 indicates that a statement remains true if the values are reversed i.e. ↑ 2 ↓ is the same as ↓ 2 ↑. 1 indicates that this relationship does not hold i.e. ↑ 1 ↓ is not the same as ↓ 1 ↑. Example statement from the top left of the diagram: 'the fallow length is greater than one year causes a decrease in the density of *esre* seed'. Differences in the shapes of nodes are not important in this context, outside of the grammar of the AKT5 software.

Figure 4.3 A diagrammatic representation of farmers' knowledge of vegetation succession on the fallow from the atwima knowledge base

Soil fertility under different fallow species

Farmers were aware of which plant species were beneficial in regenerating soil fertility on the fallow. Sometimes they were able to explain how this occurred, whereas at other times they could only state their observations without suggesting any reasons for them. Farmers were also aware of plant species associated with particular vegetation types such as secondary forest.

Panicum maximum and *Pennisetum purpureum* were two common grass species that sometimes dominated fallow land at Gogoikrom, peri-urban Kumasi and Subriso. *P. purpureum* was variously termed *hwedee* (*lit.* sugar cane) and *nantwri sre* (*lit.* cow grass). At Yabraso and Subriso *P. maximum* was referred to as *ageaboso* (*lit.* has taken

over/colonised). At Gogoikrom and in peri-urban Kumasi, farmers referred to all tall statured grasses as *esre* although they appeared to be referring to *P. maximum.*

Pennisetum purpureum was found growing vigorously on fallow land next to streams and in other moist areas. Farmers claimed that biomass accumulation under *hwedee* was high, and that soil would be soft and fertile after just three years. The roots of *hwedee* were said to ooze moisture and the soil under it was said to be moist and cool. Farmers considered that soil after a *hwedee* fallow would be more fertile than after a *Chromolaena odorata* fallow of similar duration.

Panicum maximum was also found growing vigorously in low lying areas, but also on upland where fallows were short, preventing the regeneration of broad leafed shrubs and trees. However farmers considered that unlike *P. purpureum, P. maximum* sucked water from the soil, drying and hardening it. Farmers knew that *P. maximum* was not shade tolerant, and was rapidly shaded out, particularly by *C. odorata.*

Chromolaena odorata is perhaps the most dominant fallow species in southern Ghana. Almost all (97.6%) farmers in the knowledge distribution survey named it as one of the top five weeds on their farms. Those farmers who did not mention this weed were in the driest Wenchi block where ecological conditions are less suitable and grasses become more dominant. Despite considering it a troublesome weed, 84% of farmers claimed that it was a good plant to have on their land – most frequently for its beneficial effect on soil fertility and moisture (Table 4.23).

Table 4.23 Farmers' reasons for considering Chromolaena odorata (acheampong) a good or bad plant to have on their land, elicited during the knowledge distribution survey

Reason	Type of reason*	Proportion of farmers mentioning reason (%, n=210)
The soil under *acheampong* is fertile	+	77.1
The soil under *acheampong* is moist	+	58.1
It is not as competitive as other weeds or does not injure crops	+	23.3
It shades out other weeds	+	18.1
It smothers the growth of trees	-	6.2
Its rapid growth shades or smothers crops	-	6.2

* + indicates positive attributes of *C. odorata*, and – indicates negative attributes of *C. odorata*

Farmers stated that *C. odorata* had rapid, vigorous growth, producing large quantities of leafy biomass which decomposed rapidly and added organic matter to the soil. The leaves and stems were highly combustible and burnt completely into ashes. This quality was appreciated by farmers who considered that crops did well after fallow vegetation had been completely

reduced to ashes. One explanation for this opinion is that a good burn requires sufficient leaf litter and that *C. odorata* produces a large quantity of leaf litter. Large quantities of leaf litter are associated with rapid biomass accumulation on the fallow, and hence a build up of soil organic matter. Hence a good burn is more of an indirect indicator of soil organic matter than something that enhances soil fertility in itself. A good burn may also destroy some weeds and weed seeds, although farmers were also aware that germination of some weeds was stimulated by burning (Table 4.29, Table 4.30).

Farmers also said that *C. odorata* spread rapidly on fallow land, covering the soil surface and protecting it from the sun. They claimed that it protected the soil from hardening, and made the soil moist, soft and cool. *C. odorata* was also beneficial in controlling grassy weeds. It was capable of smothering and shading out grass species such as *Cenchrus ciliaris* (*rawlings*) after two years at Yabraso and *Panicum maximum* at Gogoikrom. However, farmers also said that it smothered the growth of young trees.

Alchornea cordifolia (gyama) was another broadleaf species with rapid growth capable of colonising fallow land and leading to rapid regeneration of soil fertility. Farmers were also aware of plants which, because of their ecological niche requirement, were associated with long fallows, that is, secondary forest. These plants were often climbers and creepers or else shade tolerant species that farmers stated were found in moist areas. This type of knowledge was not confined to areas where forest fallows were still common, such as at Oda and Gogoikrom, but was also elicited from peri-urban Kumasi where forest fallows were very rare. However, although some species were mentioned in more than one location, other species differed between locations. At both Oda and Gogoikrom farmers mentioned the climber *Mormordica spp.* (*nyanya*), and the under storey species *Physalis sp.* (*totototo*), *Piper umbellatum (mumuaha)* and various ferns (*ntokuaha* or *aya* – botanical names unidentified during the research). Two types of creeper *ahomofufuo* and *akyikyerebe* (botanical names not identified) and the under storey species *Thaumatococcus danielli (ego)* were also mentioned at Oda, and an unidentified vine *nkonkahin* at Gogoikrom. In peri-urban Kumasi farmers mentioned unidentified climbing plants *sokoruwa* and *kwame dule* as well as ferns (*aya*) and the shrub *awobe* (*Phyllanthus reticulatus*).

Management of fallow vegetation and weeds

In addition to knowledge of the influence of different species on soil fertility regeneration, farmers were also aware of attributes of plant species that influenced how easy they were to clear from fallow land, and to manage during crop cultivation.

Farmers stated that both *Pennisetum purpureum* and *Panicum maximum* had to be uprooted prior to crop cultivation due to the formation of dense tussocks, unlike *C. odorata* which rooted less densely. Both grasses were very difficult to uproot, particularly *Pennisetum purpureum,* which required the use of a mattock, not just a hoe. However once uprooted *P. purpureum* was easier to control than *Chromolaena odorata* or *Panicum maximum* because it spread gradually from tillers rather than producing copious amounts of viable seed.

Once uprooted, farmers said that *Panicum maximum* resprouted from any stumps and root fragments left in the soil and they considered it necessary to dig up the stumps and burn the farm at a high intensity to kill any remnants. *P. maximum* also produced large quantities of viable seed which were easily dispersed by the wind and by birds. Farmers were also aware that germination was stimulated by burning but some farmers said that young seedlings were relatively easy to clear as compared to resprouting roots and stumps.

Farmers stated that *C. odorata* also produced large quantities of light, winged seeds which were easily dispersed by the wind. They claimed that reduction in tree density facilitated its spread through wind dispersal. Farmers explained how large quantities of viable seed resulted in the growth of a multitude of stems at the beginning of the fallow. This meant that *C. odorata* fallows were therefore very difficult to clear in the first few years. However, as a result of intra-species competition, after about four years, the number of single plants were reduced leaving widely spaced plant stands with thick stems. These were considered much easier to clear than grass fallows as they only required slashing with a cutlass and the plants did not have to be uprooted.

Although *C. odorata* was said to be easier to clear than some grass species, 80% of farmers in the distribution survey (n=210) claimed that *C. odorata* was a difficult weed to control. The most frequently cited reason was its rapid growth rate (Table 4.24). Farmers stated that it grew back rapidly from rootstock in the soil after it had been slashed so that frequent weeding was required. Farmers also mentioned its abundant seed production and rapid germination. A few farmers mentioned that hands or feet pierced by the sharp stems could cause wounds that took a long time to heal.

Table 4.24 Farmers' knowledge of factors influencing the control of Chromolaena odorata elicited during the knowledge distribution survey

Reason *acheampong* difficult or easy to control	Proportion of farmers mentioning reason (%, n=210)
Rapid growth or rapid regrowth when slashed	70.5
Difficult to uproot	48.1
Abundant seed production or rapid germination	29.5
Easy to uproot	11.0
Not necessary to uproot	1.9

A fifth of the farmers consulted, considered *C. odorata* an easy weed to control in comparison with other more noxious species because it was easy to uproot and, once uprooted, would not grow back. Some farmers said that it was relatively shallow rooted, and that burning made it easier to uproot. Others said that after uprooting it did not regrow, and slashed stems could be left on the soil as they would not root. A few farmers said that it could easily be controlled with herbicide. A few others said that it was not necessary to uproot it unless mounding or ridging and that the stems were soft and easily slashed with a cutlass.

4.4.3.3 Weed species, ecology and management

During the generalisation survey farmers were asked to name the most troublesome weeds on their farms. They mentioned a total of 74 different species, with greater species diversity in the wetter southern locations than in the drier northern ones (Table 4.25).

Table 4.25 Weed species diversity in the five blocks of the knowledge distribution survey

Block	Total number of weed species mentioned*
Asankrangua	38
Obuasi	34
Peri-urban Kumasi	30
Sunyani	24
Wenchi	27
All	74

*There were 42 respondents in each block, with each naming up to 5 weeds.

Some weed species were common to all locations, whereas others varied (Table 4.26). *C. odorata* was mentioned by all farmers except five in the Wenchi block. *Panicum maximum*, *Centrosema spp.*, *Euphorbia heterophylla*, *Rottboellia cochinchinensis* and *Sida acuta* were mentioned in all blocks. *Pennisetum purpureum* was less commonly mentioned in the wetter areas where *Paspalum conjugatum* and other short statured grasses were more frequently a problem. *Imperata cylindrica* was much more common in the Wenchi block than in the other locations.

Table 4.26 Weed species mentioned by four or more farmers during the knowledge distribution survey

Local names	Botanical or other name	Proportion of farmers mentioning weed species (%)					
		Asankrangua (n=42)	Obuasi (n=42)	Kumasi (n=42)	Sunyani (n=42)	Wenchi (n=42)	All farmers (n=210)
Acheampong, busia, topiah	*Chromolaena odorata*	100	100	100	100	88	98
Esre, ageaboso	*Panicum maximum* and other tall (1 - 2m) statured grasses	69	48	40	64	57	56
Ananse trumu huma, amantem wire, bankye_wire	*Centrosema spp (C. plumieri, C. pubescens, C. virginianum)*	55	33	60	55	12	43
Adanko milk	*Euphorbia heterophylla*	57	21	21	50	38	38
Tweta	*Sida acuta*	19	17	19	26	14	19
Nkyenkyema	*Rottboellia cochinchinensis*	21	21	21	2	26	19
Hwedee	*Pennisetum purpureum*	31	2	0	5	29	13
Eton	*Imperata cylindrica*	5	5	0	7	45	12
Nsonwia, asamoah nkwanta	*Paspalum conjugatum*	5	19	24	5	0	10
Kegya	*Griffonia simplicifolia*	5	2	10	17	0	7
Nsensan	Short statured grasses such *as Eleusine indica*	0	10	24	0	0	7
Nyanya	*Momordica spp*	5	12	10	5	0	6
Bomaguwakye	*Phyllanthus fraternus*	0	19	7	0	2	6
	Fern	0	14	5	7	0	5
Yaa asantewaa		2	12	10	2	0	5
Pepediawu	*Datura metel, D. stramonium*	2	10	7	2	0	4
Krawoni	possibley *Ageratum cornyzoides*	12	2	5	0	2	4

Farmers claimed that weeds were now more of a problem than they had been in the past due to shortening fallows. All farmers stated that the length of time land was allowed to fallow was the main determinant of the weed species to be found on that land. In addition, different weed species were found on upland and on lowland sandy soil and seasonally waterlogged lowland.

In addition to their knowledge of vegetation succession on fallow land, farmers also had knowledge of the changes in weed flora during cropping. The first weeds that appeared during the cropping phase were usually those of the natural fallow vegetation. As soil fertility became depleted these were replaced or accompanied by other more noxious weeds. Just as some plant species were associated with a long fallow, some weed species were associated with land which had been cropped intensively (i.e. annual crops had been grown for a number of years without a fallow, or successive fallows had been very short) or land where soil

fertility had been depleted. At Subriso and Yabraso these species included *Sida acuta* (*tweta*), *Commelina spp.* (*Nyamebéwu ansa namawu*), *Portulaca spp.* (*asaase ne aboo*), *Ageratum cornyzoides* (*krawoni*), *guakuro* (an unidentified small broad leaved plant), *Sporobollus pyramidalis* (*abirekyire abodwese*) and *Imperata cylindrica* (*eton*).

Farmers had a term for weeds that were particularly difficult to control - *nwura bone*. Attributes of weeds that made them particularly difficult to control were rapid growth, production of large quantities of viable seed and regrowth from roots, rhizomes or stems left on the soil. Some weeds were difficult to control because of their tangling or climbing growth habit which could pull crops over if left uncontrolled, and which required hand weeding. Other weeds were very difficult to uproot and others possessed irritant hairs or spines that made them difficult to handle (Table 4.27; Table 4.28). Weeds classed as *nwura bone* differed with location, for instance *Chromolaena odorata* was considered a *nwura bone* at Atwima but not at Wenchi where it was drier and farmers had to contend with more difficult grass weeds. Farmers' knowledge of the characteristics of various weeds is given in Table 4.29 and Table 4.30.

Table 4.27 Properties of nwura bone elicited during the knowledge distribution survey

Property	**Proportion of farmers mentioning each property (%, n=210)**
Rapid growth	89.5
Difficult to uproot	57.6
Sprouting from underground parts	44.3
Compete with, smother or entangle crops	32.4
Prolific seed production	30.0
Growth habit that necessitates hand weeding	11.4
Presence of irritant hairs or spines	10.5

Table 4.28 Attributes of most troublesome weed species elicited from 18 farmers in four villages in peri-urban Kumasi during knowledge base creation

Weed species	Reason why particularly difficult to control	No. farmers mentioning weed
Tall grasses (*esre*)	- Rapid growth - Grow back rapidly from root pieces in the soil Require either labour intensive uprooting or herbicide use	7
Short grasses (*nsensan/nsonwia*)	- Rapid growth - Grow back rapidly from root pieces in the soil - Require uprooting or the use of herbicide	5
Centrosema spp.	- Climbing habit which pulls crops down	4
Chromolaena odorata	- Rapid growth	3
Euphorbia heterophylla	- Rapid growth - Requires either very frequent weeding or uprooting	2
Imperata cylindrica	- Its deep spreading roots make it difficult to remove without uprooting crops	1
Kwame dule (a climbing plant)	- Rapid growth - Presence of spines making it difficult to weed - Climbing habit which pulls crops down	1
Anomaanomaansa (a climbing plant)	- Climbing habit which pulls crops down	1

Table 4.29 Farmers knowledge of the characteristics of some broadleaf plants as crop weeds

Local name	Botanical name	Attributes
Ananse tumu huma/Amantem wire	*Centrosema spp (C. plumieri, C. pubescens, C. virginianum)*	- Local names refer to its climbing, coiling growth and ability to 'strangle' crops such as cassava and pull them over if it is not controlled - Difficult to weed due to its climbing growth pattern - Rapid growth - Seeds profusely - Seeds germinate rapidly after land is burnt - Seeds germinate 3 months after use of a herbicide - Relatively shallow rooted - Drought tolerant - Shaded out by *Chromolaena odorata* on the fallow
Adanko milk	*Euphorbia heterophylla*	- Rapid growth - Requires frequent weeding – after slashing it regrows in one week - Easy to uproot - Seeds profusely with a high germination rate - Seed is not destroyed by burning - Shade tolerant - An annual, does not survive the dry season
Tweta	*Sida acuta*	- Deep rooted - Very difficult to uproot – a hoe is necessary. (Its name means 'pull with flatulence') - Resprouts when cut - Seeds profusely and has a high germination rate - Burning promotes seed germination - Spreads through seed - Drought tolerant - Perennial weed

Table 4.29 continued

Local name	Botanical name	Attributes
Nyanya	*Momordica spp*	- A climber with rapid growth leading to fast colonisation of fallow land - One of the first weeds to appear growing from seed left in the soil after clearing a secondary forest fallow - Has a central root making it easy to weed and clear - Does not regrow when uprooted - Not tolerant of dry soil
Aya	A fern	- Found in wet shady areas, particularly after long fallows and in cocoa farms - Reproduces and spreads rapidly
Nyamebéwu ansa namawu	*Commelina spp. (C. benghalensis, C. diffusa, C. erecta, C. forskalaei)*	- Literal name emphasizes the persistence of this weed: "until God dies I shall never die" - Rapid growth - Produces roots from nodes on the stem and spreads through this rooting mechanism - Even when uprooted and turned upside down it is difficult to eradicate - Roots are not destroyed by burning - Succulent drought resistant species, stem retains moisture even in the dry season - Indicates a reduction in soil fertility when found on crop land
Apea	*Mucuna pruriens*	- Contact with the pods causes intense skin irritation making this a difficult weed to clear from fallow land. Pods explode when they have dried out (during the dry season) and can come into contact with skin in this way - Climbing growth habit - Can be uprooted with a cutlass - Low tolerance to shade
Kwame dule	Unidentified	- Climbing growth habit: winds itself around crop stems and pulls them over - Rapid growth - Presence of spines makes it difficult to remove - Found after a mature fallow
Nkaseenkasee	*Alternanthera pugens*	- Its literal meaning is 'thorny' - Its thorns make it difficult to uproot
Asaase ne oboo	*Portulaca spp. (P. foliosa, P. paniculatum, P. oleracea and P. quadrifida)*	- Its name means 'soil and stones' as it is able to grow over rock and concrete - Produces roots from nodes on the stem - Tolerant of moisture stress - Indicates a reduction in soil fertility when found on crop land - Creeping growth habit does not choke tall crops
Bosumwuajura, bokoboko	*Talinum triangulare*	- Difficult to eradicate - Resprouts from root fragments left in the soil - Resprouts when uprooted and placed in a heap - Difficult to eradicate with herbicides - High rate of seed production and germination - High shade tolerance - Short creeping growth habit that does not shade tall crops - Leaves may be eaten as a vegetable - Considered an indicator of fertile soil at Subriso and Yabraso - Perennial weed

Table 4.30 Farmers' knowledge of the characteristics of some grasses and sedges as crop weeds

Local Name	Botanical name	Attributes
Nkyenkyema	*Rottboellia cochinchinensis*	- Grows rapidly - Has dispersed growth pattern - Easier to clear than Panicum maximum but less easy than Chromolaena odorata and Centrosema spp. - Will not regrow if plants are slashed at a very early age - Seeds profusely - Burning stimulates seed germination - Irritant hairs are present on the leaves - Use of Roundup is an effective method of clearing - Not tolerant of dry soil - At Wenchi a fallow dominated by a vigorous growth of *nkyenkyema* with large bases might be considered suitable for cultivation
Eton	*Imperata cylindrica*	- Has deep roots which also spread laterally making it difficult to uproot - Roots can pierce root and tuber crops
Nsonwia, Asamoah Nkwanta	*Paspalum conjugatum*	- Short statured grass - High density of formation of roots at root nodes - Spreads through creeping roots and seed production - Has very small seeds - Resprouts from roots left in the soil - Must be uprooted with a hoe - Roots survive burning - Drought resistant - Indicates a reduction in soil fertility at Oda
Sesan, nsensan	short statured grasses such as *Eleusine indica*	- Short statured grasses - High density of root formation at root nodes - High density of roots which do not spread, but survive the dry season - Sometimes also called "*abirekyire abodwesé* (the he-goats beard) - Difficult to uproot - Seed and roots are not destroyed by burning
Rawlings	*Cenchrus ciliaris*	- First noticed at Wenchi with the coming into power of the Head of State, President Rawlings - Rapid growth - Profuse seed production - Seeds are very small and wind dispersed - High density of shallow roots - Roots survive the dry season and start sprouting again when the rains arrive - Where found in profusion indicates hard, infertile soil with low moisture availability
Abusua hwedeé	*Sorghum lalepense*	- Very deceptive as it resembles the grain sorghum - Found on hard soil

Farmers had knowledge of various factors which influence weed growth that could potentially be used to control weeds. They named a number of mechanisms for the dispersal of weed seeds (Table 4.31). At the landscape level, they considered that the reduction in trees increased wind speeds and aided the dispersal of wind dispersed weeds such as *C. odorata*. They stated that light stimulates germination and weed growth, but that high sunlight intensity in the dry season reduces weed growth. They named a number of ways of reducing the light

available to weeds (Table 4.32). The most commonly mentioned was manipulating plant spacing or intercropping to ensure rapid canopy formation. Mulching, tree cover and cover crops were also mentioned. They stated that changes in soil fertility influenced weed growth with weeds out competing crops where fertility is low. They named ways of reducing weed seeds on the farm. The most commonly mentioned was weeding before weeds had set seed, although this appeared to be less practised than the other methods mentioned: burning fallow vegetation, fallowing and using herbicide (Table 4.33). Farmers also stated that the most effective time to weed was when weeds were very small, although again, they clearly did not always practice this (Table 4.34).

Table 4.31 Farmers' knowledge of weed dispersal mechanisms elicited during the knowledge distribution survey

Mechanism	Proportion of farmers mentioning mechanism (%, n=210)
Wind	98.6
Shoes and clothing	55.2
Birds	50.0
River	29.0
Mammals	28.1
Explosion	11.9
Timber machinery	9.0
Runoff water	5.7

Table 4.32 Farmers' knowledge of ways to reduce the light available to weeds elicited during the knowledge distribution survey

Ways of reducing the light available to weeds	Proportion of farmers mentioning method (%, n=210)
Planting crops at close spacing or intercropping so that canopy formation is rapid	78.1
Mulching with slashed weeds	41.0
Tree planting or selective felling of trees	25.7
Planting a cover crop	1.9

Table 4.33 Farmers' knowledge of ways to reduce weed seeds on the farm elicited during the knowledge distribution survey

Ways of reducing weed seeds on the farm	Proportion of farmers mentioning method (%, n=210)
Weeding before weeds have flowered and set seed	83.3
Burning cleared vegetation	33.8
Fallowing	24.8
Herbicide use	11.9

Table 4.34 Farmers' knowledge of the most effective stage to clear weeds from the farm so that they don't compete with crops or regrow elicited during the knowledge distribution survey

Most effective stage	Proportion of farmers mentioning stage (%, n=210)
Very young – the two or three leaf stage	33.3
Before setting seed	89.0

4.4.3.4 Herbicides

Around a third of farmers interviewed in the generalization survey said that they had used a herbicide in the past. Gender appeared to be the most significant influence (p=0.000) with nearly half of all men having used a herbicide, compared to less than one fifth of women. In addition to gender, both farmers with more education and those having some individual contact with the extension services were significantly more likely to have used a herbicide. Farmers in the Wenchi block were least likely to have used one whereas those in the Sunyani and Kumasi blocks were most likely.

At the time of the survey (March, 2002), herbicides available in Kumasi Central market were Roundup (glyphosate), atrazine, Gramoxone (paraquat) and Calliherbe (2, 4 D). More than 40% of farmers were able to name at least one herbicide comprising mainly of the 95.5% of farmers who had used herbicide in the past but also 19.6% of other farmers. Roundup was the most commonly mentioned (by 87 % of all farmers who named a herbicide), followed by atrazine (49 %) and Gramoxone (48 %). Other herbicides mentioned were Calliherbe, Rilof (piperophos and propanil) and basagram (bentazone).

During interviews to elicit farmers' knowledge, farmers stated that the effectiveness of herbicide was influenced by the height and age of the weeds – effective control was obtained with weeds 30 cm tall but not those of 60 cm. Herbicide was stated to be more effective in the rainy season than the dry season. Effectiveness was also influenced by the strength of the solution and the type of weed. Some farmers were aware that Roundup requires a short period without rain (four hours) after application. Roundup was said to keep land free of weeds for three months, whereas weeds would start regrowing more quickly than this if Gramoxone was used. However Gramoxone was used more than Roundup on tree crop plantations in the dry season. Farmers also mentioned using dirty water, exposing the chemical to the air and strong sunshine as influencing the effectiveness of herbicide.

The generalisation survey confirmed that knowledge about the selectivity of different herbicides and of the factors influencing their effectiveness was unevenly distributed amongst farmers. Previous herbicide users had more knowledge (Table 4.35, Table 4.36), but even amongst this group there were low levels of response to some questions.

Table 4.35 Knowledge of the selectivity of Roundup and Gramoxone amongst previous herbicide users and non-users

Aspect of knowledge	% positive response			P	
	All farmers, (n=210)	Previous users (n=67)	Non users (n=143)		
Roundup is a non selective herbicide	34.8	76.1	15.4	0.000	***
Gramoxone is a non selective herbicide	14.3	35.8	4.2	0.000	***

*** $p \leq 0.001$

Table 4.36 Knowledge of factors influencing the effectiveness of Roundup amongst previous herbicide users and non-users

Factor	% positive response			P	
	All farmers (n=210)	Previous users (n=67)	Non users (n=143)		
Any response	31.0	70.1	12.6	0.000	***
Rainfall within four hours of application	15.7	40.3	4.2	0.000	***
Strength of herbicide solution	19.0	40.3	9.1	0.000	***
Weed height	2.9	7.5	0.7	0.022	*
Type of weed	6.7	17.9	1.4	0.000	***

*** $p \leq 0.001$
* $p \leq 0.05$

Overall, farmers who had used a herbicide in the past had significantly more knowledge than farmers who had not. Differences in knowledge between men and women who had never used herbicide were significant for two questions so that men had more knowledge than women. Farmers from Kumasi, and then those in Asankrangua, had more knowledge than farmers in the other blocks. Farmers in the Asankrangua and Obuasi blocks may have known more about Gramoxone, which is more suitable for use on tree crop plantations, but about which there were fewer questions than for Roundup.

4.4.3.5 Burning during land preparation

The most important reason for burning vegetation debris was to remove it from the farm and make it easier to work on (Table 4.37). Leaving it to decompose was simply considered impractical in most cases and would slow down many of the tasks carried out on the farm. Furthermore, although it might be possible with plantain and cassava, crops such as maize would be easily damaged when the farmer tried to move around a farm covered with branches from trees and shrubs.

Table 4.37 Farmers' knowledge of the influence of burning cleared vegetation on soil and crop cultivation

Influence of burning	Proportion of farmers giving response (n=210)
Makes it easier to work on the farm	81.4
Creates ash which acts like fertiliser	46.2
Reduces weed growth	39.5
Destroys pests and diseases in the soil	22.4
Enhances the sprouting of cocoyam	14.3
Decreases the nutrient content of the soil, increases soil temperature, causes cracking or makes land hard	6.7
Makes crops grow fast	3.8
Makes the soil friable so that water infiltrates well	1.9

Burning was an important tool in weed and pest management. Farmers said that it enabled crops to germinate before weeds developed. Weeds sprouted less quickly from roots and stumps left in the soil and some weed seeds were destroyed by burning. The quantity of vegetation to be burnt, and its moisture content, influenced the intensity of the burn, and hence the effectiveness of the destruction of roots and stumps. An intense burn was considered particularly important to destroy grasses (*esre*). Farmers knew that burning could stimulate the germination of some weeds e.g. *Rottboellia cochinchinensis, Sida acuta* and *Centrosema spp.* However they found these weeds easier to clear than sprouting roots and stumps. Burning was also said to reduce termites, other insect pests and millipedes.

Burning was known to enhance crop growth. Farmers stated that ash was like fertiliser and that burning made the soil friable and could increase water infiltration. They also said that the germination of cocoyam and oil palm, both of which occur naturally in the soil in forest areas, is stimulated by burning. At Oda farmers claimed they could not grow cassava if land was not burnt.

Some farmers were aware of negative effects of burning. They said that it could dry out the soil, make it hard, decrease water infiltration, reduce fertility and kill earthworms. However, while only few farmers (7.1%) mentioned these negative effects nearly all (98.6%) mentioned positive effects (Table 4.37).

Knowledge distribution appeared to be fairly even. Farmers in the Kumasi and Asankrangua blocks were significantly more likely to state that burning enhanced the sprouting of cocoyam (p=0.000) than farmers in the other blocks. Cocoa farmers were similarly more likely to state this than farmers without cocoa. Farmers in the Wenchi block were less likely to mention that burning decreased weed growth on the farm (p=0.001). Men and vegetable cash croppers

were more likely to state that burning the farm produces ash which acts like fertiliser ($p=0.003$, $p=0.033$ respectively).

4.4.3.6 Maintaining soil cover and the use of cover crops

Maintaining soil cover was an important ecological principle that all farmers were aware of. Nearly all farmers (95.7%) stated that having the sun shining on bare soil was bad. Most farmers (71.6%) stated that the absence of soil cover made the soil hard. Others said that it made the soil hot and dry and caused cracking (Table 4.38). A few mentioned a reduction in soil fertility and crop growth and the invasion of weeds.

Table 4.38 Farmers' knowledge of the effect of the sun on bare soil

Effect of the sun on the soil	% positive response (n=201)
Makes soil hard	71.6
Makes soil hot	48.8
Dries the soil out	39.8
Causes the soil to crack	28.9

One of the advantages of the traditional mixed cropping method of cultivation was to maintain soil cover in order to reduce weed growth, protect the soil and conserve moisture. Over 90% of farmers said that retaining trees and shrubs on their farms protected the soil from the sun (Table 4.39). Farmers stated that trees shaded the soil, made it cool, and had a positive influence on soil moisture. This was particularly mentioned with respect to sandy soil which heated up quickly when the sun was shining on it. Mulching crops with slashed weeds was also mentioned.

Table 4.39 Methods known by farmers for protecting the soil from the sun

Method	% positive response (n=201)
Retaining trees and shrubs on the farm	90.6
Mixed cropping e.g. plantain and cocoyam to provide canopy cover	63.2
Mulching with slashed weeds	35.8
Cultivation of cover crops	4.0

Farmers in the Obuasi and Asankrangua blocks, and plantain and cocoa cash croppers, were more likely to mention mixed cropping as a method of maintaining soil cover. Maize cash croppers were more likely to mention mulching with slashed weeds.

Using weeds to mulch the soil

Farmers stated that weeds spread on the soil surface decompose to form organic matter, and cover the soil preventing the germination of weed seeds and regrowth of existing weeds (Table 4.40). They also protect the soil from the sun and conserve soil moisture. When weeds were heaped around the base of cassava they protected the tubers from grasscutters.

Table 4.40 Farmers' reasons for mulching the farm with slashed weeds

Reason for mulching	% positive response (n=210)
To add organic matter to the soil	89.0
To prevent weed growth	58.6
To prevent the soil from heating up	40.0
To prevent the soil from becoming hard	17.1
To conserve soil moisture	16.7
Increases crop growth and yield	9.5
To prevent surface runoff and soil erosion	4.8
To protect crops from rodents	3.8

Farmers did not always mulch the soil with slashed weeds. Farmers said that weeds that would regrow were heaped in one place. They also said that heaping weeds to the side of the farm made it easier to move around the farm, prevented insect pests such as termites from hiding in the debris and aided the circulation of air around the crop.

Cultivated crops as soil cover

There was a high level of awareness of the principle of maintaining soil cover using cultivated crops and of the decomposition of vegetative biomass contributing to soil fertility. However, farmers were more aware of food crops which maintain soil cover as a subsidiary ecological benefit, than legumes promoted by international research institutions, whose main function is soil improvement, and which have little food value. Cover crops were explained to farmers as plants that covered the soil and could contribute to organic matter through their decomposition.

The majority of farmers were familiar with the local names of leguminous cover crop genera which have species that are common weeds (Table 4.41). Thus they were aware of some species of *Mucuna* and *Centrosema*, but not *Canavalia* or *Pueraria*.

Table 4.41 Farmers' familiarity with the names of leguminous cover crop genera

Botanical name	Local name	Percentage of farmers who had heard of the cover crop name (n=210)
Mucuna	*Adua apea*	93.8
Centrosema	*Ananse dukono, ananse trumu huma, amantem wire*	86.7
Canavalia	No local name	11.0
Pueraria	No local name	1.9

When asked to name cover crops the names given by farmers were not restricted to legumes. More than 60 % of farmers named sweet potato and cucurbit. The main legumes mentioned were cowpea and groundnut (Table 4.42). Other plants mentioned by just a few farmers were the weed *Talinum triangulare,* calabash (*Lagenaria siceraria*), bambara beans (*Vigna subterranea*) and *krobonko* (*Telfairia occidentalis* – fluted pumpkin).

Table 4.42 Other cover crops named by farmers

Local name	Botanical name	Description and uses	Percentage of farmers who named cover crop name (n=210)
Santum	*Ipomoea batatans*	Sweet potato	60.5
Beans	*Vigna unguiculata*	Cowpea	59.0
Efre	*Cucurbita maxima* and *C. pepo**	A cucurbit with a yellow flower and fruit and flesh. Probably pumpkins and vegetable marrows.	53.8
Akatoa/ agushie/ akate	*Cucumeropsis mannii**	Probably a white melon. Edible seeds of *agushie* are roasted and eaten, or else ground and used in soups and stews.	20.5
Nkatee	*Arachis hypogaea*	Groundnut	7.1
Pompohuro	*Citrullus lanatus**	Water melon	5.7

*Correct identification of the cucurbits is difficult from the local names given by informants. *Egushi* is a general name in West Africa for any cucurbit seeds which are ground and used in cooking. However informants did appear to be referring to three separate groups of edible plants as does Abbiw (1990).

Approximately three quarters of farmers were able to name a beneficial attribute of cover crops. Conservation of soil moisture was the most common attribute given, followed by increase in soil organic matter and reduction in weed growth (Table 4.43). Over 75 % of farmers were able to describe the cultivation of one of these cover crops, 69.6% of which were intercropped. Approximately one third of these farmers described cultivation of cowpea or groundnut, two fifths described cultivation of a curcurbit or sweet potato, and a quarter described cultivation of mucuna, centrosema or canavalia.

Table 4.43Farmers knowledge of the beneficial attributes of cover crop cultivation

Attribute	Percentage of farmers naming attribute (n=210)
Conservation of soil moisture	54.3
Increase in soil organic matter	36.2
Reduction in weed growth	21.9
Decrease in soil erosion	17.1
Source of plant nutrients	11.0
Source of human or animal food	5.2
Shading of the soil	4.3
Nitrogen fixation	2.9
Reduction in soil borne nematodes	0.5
Don't know	25.2

4.4.4 The integration of trees on crop land

Farmers had some knowledge of the influence of trees in general, on fallow land (Section 4.4.3), and when integrated with crops. They also had knowledge of the influence of different tree species on crop growth.

4.4.4.1 The influence of trees on soil fertility

Farmers associated some trees with fertile soil because they produced large quantities of leaf, flower or fruit litter that decomposed rapidly and contributed to organic matter and soil fertility on farm as well as fallow land (Table 4.44). Farmers said that the woody parts of some trees e.g. *Ceiba pentandra*, decomposed rapidly, adding to soil organic matter, even during cropping. Others decomposed only very slowly e.g. *Piptadeniastrum africanum* and *Milicia excelsa* and were therefore, considered less beneficial. Farmers frequently mentioned that plantain did well when planted close to the decomposing trunks or branches of *Ceiba pentandra* - which was itself a very common tree.

Table 4.44 Trees recognised to have a positive effect on soil fertility through litter fall or the rapid decomposition of woody parts

Local name of tree	Botanical name	Reason given for positive effect
Onyina	*Ceiba pentandra*	Produces abundant leaf litter and flower fall at the start of the dry season Woody parts decompose rapidly
Domini and *doma*	*Ficus capensis* and other *Ficus spp.*	Abundant fruit fall
Wama	*Ricinodendron heudelotii*	Abundant fruit fall
Nyamedua	*Alstonia boonei*	Litter fall
Kumanini	*Lannea welwitschii*	Rapid decomposition of woody parts
Wawa	*Triplochiton scleroxylon*	Rapid decomposition of woody parts, but slow decomposition of leaves

Farmers associated other trees with a positive or negative impact on crop growth or soil fertility without being able to explain why. Sometimes farmers had contradictory knowledge about the same species (Table 4.45).

Table 4.45 Farmers knowledge of the association of trees with different levels of soil fertility

Local name of tree	Botanical name	Associated level of soil fertility (comparative)
Kyenkyen	*Antiaris toxicaria*	High
Kokoanisua	*Spathodea campanulata*	High
Pepediawu	*Solanum erianthum*	High
Mahogany	*Khaya spp.*	High
Foto	*Glyphaea brevis*	High
Aweamfosamena	*Albizia ferruginea*	High
Keyja	*Pterygota macrocarpa*	Low
Funtum	*Funtumia elastica*	Low
Nyanyafrowa	*Mallotus oppositifolius*	Low
Kakapenpen	*Rauvolfia vomitoria*	Contradictory

4.4.4.2 The influence of trees on soil moisture

Farmers had knowledge about how different tree species influenced soil moisture availability. They observed the influence of trees on soil moisture by observing soil conditions under the tree. Soil under trees considered to have a low water uptake would be moist throughout the year whereas soil under trees with a high moisture uptake would be dry throughout the year

with a hard physical structure. The cut roots of trees also provide evidence of high moisture uptake when they oozed moisture for a period after cutting.

Some tree species were known to make the soil moist and 'cool', whereas others were known to suck a lot of water out of the soil making it dry and hard or compact (Table 4.46). Sometimes different farmers had contradictory opinions about a particular species, most notably for *kakapenpen* (*Rauvolfia vomitoria*), *onyina* (*Ceiba pentandra*) and *wawa* (*Triplochiton scleroxylon*). Some tree species were common throughout the study area e.g. *Ceiba pentandra* and *Triplochiton scleroxylon*, whereas others were mentioned by farmers at only one or two locations e.g. *Parkia biglobosa* and *Cylicodiscus gabunensis*. Farmers clearly had knowledge about different species at different locations although the knowledge represented in Table 4.46 is not intended to be comprehensive.

Table 4.46 Farmers' knowledge of tree crop competition for water at the five field sites.
+ indicates that a tree species produced little competition with crops or had a positive influence on soil moisture availability, - indicates the opposite

Local name	Botanical name	Oda	Atwima	Peri urban Kumasi	Subriso	Yabraso
Pampena	*Albizia adianthifolia*	-				
Okoro	*Albizia spp.*	-	-		-	
Nyamedua	*Alstonia boonei*	+			+	
Kyenkyen	*Antiaris toxicaria*	-				
Akata, akonkodie	*Bombax buonopozense*	+			+	
Onyina	*Ceiba pentandra*	+			+	-
Esa	*Celtis mildbraedii*	-	-			
Watapuo, awapuo	*Cola gigantea*				-	
Denya, nyinakobine	*Cylicodiscus gabunensis*	-				
Senya	*Daniellia oliviera*			+		+
Domini	*Ficus capensis*		+			
Nyankyerene	*Ficus exasperata*	-	-		-	
Doma	*Ficus spp.*	+	+	+	+	
Funtum	*Funtumia elastica*	+	-		+	
Mahogany	*Khaya spp.*	+			+	+
Kwakwuedauba	unidentified				+	
Nyanyafrawa	*Mallotus oppositifolius*		-			
Mango	*Mangifera indica*				+	
Papea	*Margaritaria discoidea*				-	+
Odum	*Milicia excelsa*	+		-		-
Sasamamsa	*Newbouldia laevis*		+			
Nworama	unidentified				+	
Srono	*Parkia biglobosa*					+
Esia	*Petersianthus macrocarpus*	+				
Awobe	*Phyllanthus reticulatus var. glaber*				+	
Dahoma	*Piptadeniastrum africanum*	-			-	
Keyja	*Pterygota macrocarpa*		-			
Kakapenpen	*Rauvolfia vomitoria*		-		+	
Odoma kokoo	*Ficus spp./Ficus capensis*		-			
Wama	*Ricinodendron heudelotii*	+			+	
Kokoanisua	*Spathodea campanulata*				+	
Emire	*Terminalia ivorensis*	+		+		
Ofram	*Terminalia superba*	+			+	
Sesea	*Trema orientalis*				+	
Wawa	*Triplochiton scleroxylon*	-		+	-	+
Kranku	*Vitellaria paradoxa*					+

Farmers were aware of two mechanisms by which some trees made surface soil moisture available to other crops. They claimed that some trees drew a lot of water from the soil, particularly in the dry season, but gave it back to crops in the form of dew which could be observed early in the morning dripping from the leaves. Notable species were *onyina* (*Ceiba pentandra*), *doma (Ficus sur), kokoanisua* (*Spathodea campanulata)* and *akata (Bombax buonopozense).*

Other trees had deep roots which transferred water from deep down to surface soil horizons. Notable species were *wama (Ricinodendron heudelotii)*, *kokoanisua (Spathodea campanulata)* and *doma (Ficus sur)*. Some farmers also associated the moist soil found under *doma (Ficus sur)* with the high moisture content of its abundant fruits which fall to the ground and attract snails. Conversely, farmers associated trees with a high moisture uptake with wide, shallow, spreading roots - including *okoro (Albizia spp)*, *wataputo (Cola gigantea)*, *pampena (Albizia adianthifolia)*, *genegene (Cedrela spp)* and *abe (Elaeis* guineensis), or absence of a tap root – *wawa (Triplochiton scleroxylon)*. These trees interfered with soil tillage and competed with crops for soil moisture. *Nyankyerene (Ficus exasperata)* was also frequently mentioned by farmers who had observed water oozing from the stump for some time after it was felled, and thought that it drew a lot of water from the soil.

4.4.5 Inorganic fertiliser

As the regular use of inorganic fertiliser was primarily restricted to commercial vegetable growers and some rice farmers, it was expected that knowledge of inorganic fertiliser would be unevenly distributed within, and between sites. Over 60 % of farmers said that they had used fertiliser at least once in the past including almost 90 % of all commercial vegetable farmers as opposed to 55 % of other farmers. Amongst non-vegetable farmers, farmers with more education and those with off-farm income were significantly more likely to have experience of fertiliser use.

Farmers only differentiated between different types of fertiliser when asked to. Most of their knowledge was expressed in general terms for any inorganic fertiliser. Compound fertiliser such as 15:15:15 NPK was the most common fertiliser in use. Farmers said that inorganic fertiliser increased vegetative crop growth, fruit size and overall yield (including that of plantain suckers). It could prevent stunted growth on infertile soil and if crop leaves were yellow, it could make them green. They said it could speed up oil palm growth so that plants started fruiting earlier. Farmers said that fertiliser made the soil fertile and some said that it 'made the soil cool'. A few farmers mentioned that fertiliser use reduced black ant and termite problems at the base of plantain.

Knowledge about different types of fertiliser and their function was unevenly distributed (Table 4.47). Farmers with experience of fertiliser use had more knowledge than non users and this pattern was repeated with other more detailed aspects of fertiliser use (Table 4.49). Sulphate of ammonia was considered to enhance flowering and fruit set in tomato and garden egg. Some farmers considered that it dissolved more rapidly and was for use in the dry

season. The effect of compound fertiliser was considered to last longer than sulphate of ammonia.

Table 4.47 Knowledge of previous inorganic fertiliser users and non users of different types of fertiliser

Aspect of knowledge	% positive response			P	
	All farmers (n=210)	Previous users (n=129)	Non-users (n=81)		
Knew the name at least one compound fertiliser	56.7	79.1	21.0	0.000	***
Knew the name at least one nitrogen based fertiliser	61.9	83.7	27.2	0.000	***
Described compound and nitrogen fertilisers: giving any response	69.5	90.7	35.8	0.000	***
Described compound and nitrogen fertilisers: giving features of each	51.4	76.0	12.3	0.000	***
Able to name a foliar fertiliser	5.2	8.5	0	0.017	*

*** $p \leq 0.001$
* $p \leq 0.05$

Overall, the majority of farmers appeared to have some general knowledge about the potential of fertiliser (Table 4.48) Greater consensus occurred with the responses to the multiple choice survey (the last four rows of Table 4.48). Three out of four of these fairly specialised questions obtained around 80 % consistent responses whereas only two out of six of the other less specialised responses in the same table obtained an over 80 % response rate. Farmers with past experience of fertiliser use generally gave more positive responses to each question, but differences were only sometimes significant. Women who had previously used fertiliser were significantly more likely to state that it reduced black ant and termite attack on plantain than men who had used fertiliser (p=0.008). A few farmers stated that fertiliser makes the soil loose, hot or increases soil acidity.

Table 4.48 Knowledge of the effect of inorganic fertiliser on crops and soil fertility by previous inorganic fertiliser users and non-users

Effect of inorganic fertiliser	% positive response			P	
	All farmers (n=210)	Previous users (n=81)	Non-users (n=129)		
Increases crop yield	91.4	95.3	85.2	0.010	**
Increases crop growth rate	71.9	77.5	63.0	0.022	*
Increases crop vegetative growth	47.6	51.2	42.0	0.194	
Don't know the effect of fertiliser on crops	1.9	0.0	4.9	0.042	*
Makes the soil fertile	93.8	94.6	92.6	0.562	
Makes the soil cool	17.1	20.2	12.3	0.144	
Increases weed growth	53.3	58.1	45.7	0.078	
Don't know the effect on the soil	1.4	0.0	3.7	0.109	
Decreases the palatability of tomato	91.4	89.1	95.1	0.136	
Decreases the shelf life of tomato	91.0	89.1	93.8	0.250	
Decreases the quality of cassava for *fufu*	85.7	90.7	77.8	0.009	**
Reduces black ant and termite attack	31.6	37.5	22.2	0.023	*

** $p \leq 0.01$
* $p \leq 0.05$

Farmers knew that applying too much fertiliser could be damaging and said that it caused leaves to become thick and crumple, or that plants died (Table 4.49). They also said that it could make cabbage go to seed, vegetables rot quickly, cause excessive vegetative growth or scorch crops if it did not rain. A few farmers also mentioned premature flower or fruit fall. Farmers were aware of the need for care in the application of fertiliser to avoid crop scorching when fertiliser came into contact with plants, when the soil was too dry, or when too much fertiliser was applied.

Table 4.49 Knowledge of practical aspects of fertiliser use amongst previous fertiliser users and non-users

Aspect of knowledge	% positive response			P	
	All farmers (n=210)	Previous users (n=129)	Non-users (n=81)		
Awareness of negative effects of excessive application of fertiliser	52.4	71.3	22.2	0.000	***
Awareness of fertiliser causing crop scorching	64.3	81.4	37.0	0.000	***
Fertiliser scorches crops when it comes into contact with them	64.4[a]	64.8[b]	63.3[c]	0.885	
Fertiliser scorches crops if the soil is too dry	12.6[a]	15.2[b]	3.3[c]	0.155	
Fertiliser scorches crops if too much is used	71.9[a]	75.2[b]	60.0[c]	0.102	
Don't know how fertiliser scorches crops	1.5[a]	1.9[b]	0[c]	1.000	
Able to describe fertiliser application to a crop of farmers' choice	62.4	98.4	4.9	0.000	***
~~Consider fertiliser could be bad for~~ the soil	~~23.9~~	~~27.1~~	~~18.8~~	~~0.167~~	
Do not consider fertiliser could be bad for the soil	56.9	65.1	43.8	0.002	**
Don't know if fertiliser could be bad for the soil	19.1	7.8	37.5	0.000	***

[a]n=135 [b]n=105 [c]n=30
*** $p \leq 0.001$
** $p \leq 0.01$

Negative aspects of regular fertiliser use were unknown to the majority of farmers (76 %) (Table 4.49). Amongst the remaining farmers there was a belief that regular fertiliser use would lead the land to loose its ability to sustain crop growth without it. Others considered that the soil would become hard or lose its fertility, and that regular use would lead to the invasion of noxious weeds.

Men had significantly more knowledge about different types of fertiliser. Amongst farmers who had used fertiliser in the past, more men than women were able to name a compound fertiliser (p=0.021), to describe the difference between compound and nitrogen fertilisers (p=0.007) and had some knowledge of foliar fertilisers (p=0.037) but more women than men stated that fertiliser influenced black ant and termite attack on plantain, and fewer stated that fertiliser could be bad for the soil (p=0.036). More fertiliser users in Sunyani and Wenchi blocks (p=0.036), vegetable farmers (p=0.014) and northern farmers (p=0.004) stated that long term fertiliser use could have a negative effect on the soil than other farmers.

4.4.6 Animal manure

Over two-thirds of farmers (69.1%) had used animal manure (at least once) in the past. This included significantly more men (80.0%) than women (57.8%) but it is unlikely that many of these farmers used animal manure on a regular basis.

The vast majority of farmers were aware that animal manure could be used as fertiliser, most mentioning goat, sheep, cattle or poultry manure (Table 4.50).

Table 4.50 Knowledge amongst previous animal manure users and non-users about the potential of different types of animal manure as a fertiliser

Type of manure	% positive response			P	
	All farmers (n=210)	Previous users (n=143)	Non-users (n=64)		
Goat or sheep manure	91.0	95.8	79.7	0.000	***
Cattle manure	74.3	77.6	65.6	0.069	
Pig manure	7.6	8.4	6.3	0.801	
Poultry manure	76.7	80.4	67.2	0.038	*

*** $p \leq 0.001$
* $p \leq 0.05$

The majority of farmers were aware that manure had a positive effect on crop growth and yield (Table 4.51). A smaller number of farmers said that it added nutrients to the soil on decomposition, improved soil texture making it easier to dig and improved water holding capacity.

Table 4.51 Knowledge amongst previous animal manure users and non-users about the effect of animal manure on the soil, crops and weeds

Aspect of knowledge	% positive response			P	
	All farmers (n=210)	Previous users (n=143)	Non-users (n=64)		
Increases crop yield	87.1	90.9	78.1	0.012	*
Increases crop growth rate	71.4	69.2	78.1	0.188	
Source of plant food	38.6	47.6	18.8	0.000	***
Improves soil texture	31.4	30.8	34.4	0.607	
Source of organic matter	24.8	30.1	10.9	0.003	**
Makes soil easier to dig	19.0	19.6	18.8	0.889	
Improves water holding capacity	8.6	10.5	1.6	0.052	

*** $p \leq 0.001$
** $p \leq 0.01$
* $p \leq 0.05$

Farmers know that poultry manure was similar to inorganic fertiliser. They said it increased crop yield (including the number of plantain suckers), made crop leaves green (particularly rice), and helped to control black ants and termites at the base. Farmers considered that poultry manure released nutrients more slowly than inorganic fertiliser and did not spoil the

shelf life or taste of fruit. Neither was it said to increase flower set. However farmers did say that it increased weed growth. These specific properties were less frequently stated than the more general effects of poultry manure on crop growth and yield. Less than half of farmers considered that poultry manure could increase weed growth or confirmed that poultry manure did not change the taste of vegetables (Table 4.52).

Table 4.52 Knowledge amongst previous animal manure users and non-users about poultry manure

Aspect of knowledge	All farmers (n=210)	Previous users (% positive response, n=143)	Non-users (% positive response, n=64)	P
Poultry manure does not change the palatability of vegetables	49.0	53.8	37.5	0.030 *
Poultry manure increases weed growth	38.1	36.4	42.2	0.425

* $p \leq 0.05$

The majority of farmers lacked knowledge on the practical aspects of the use of animal manure (Table 4.53). Only 8.6% were aware that animal manure could scorch crops, and more than 50% thought that fresh manure could be used on crops.

Table 4.53 Knowledge amongst previous animal manure users and non-users about the use of animal manure

Aspect of knowledge	% positive response			P
	All farmers (n=210)	Previous users (n=143)	Non-users (n=64)	
Consider that animal manure can scorch crops	8.6	10.5	4.7	0.171
Consider that animal manure cannot scorch crops	87.1	89.5	81.3	0.103
Consider that fresh animal manure can be used on crops	52.2	51.0	54.7	0.628
Consider that fresh animal manure cannot be used on crops	41.1	47.6	26.6	0.005 **

** $p \leq 0.01$

The most common reason stated for crop scorching was insufficient decomposition of the manure (Table 4.54). Contact with crops and lack of moisture in the soil were also stated.

Table 4.54 Knowledge amongst previous animal manure users and non-users about how animal manure scorches crops

Reason animal manure scorches crops	% positive response		
	All farmers (n=18)	Previous users (n=15)	Non-users (n=3)
Insufficient decomposition	66.7	73.3	33.3
Contact with crops	38.9	46.7	0
Lack of moisture in the soil	5.6	6.7	0

Farmers mentioned heaping manure, keeping it moist, turning it, mixing it with sawdust and spreading it out to dry as methods of ensuring speedy decomposition (Table 4.55).

Table 4.55 Knowledge amongst previous animal manure users and non-users about methods to ensure speedy decomposition of manure

Method of manure decomposition	% positive response			P	
	All farmers (n=88)	Previous users (n=68)	Non-users (n=17)		
Heaping	47.7	42.6	58.8	0.000	***
Keeping manure moist	44.3	48.5	29.4	0.156	
Turning	33.0	35.3	17.6	0.162	
Spreading manure out to dry	14.8	13.2	23.5	0.498	
Mixing manure with sawdust	6.8	7.4	0	0.564	
Don't know	8.0	8.8	5.9	1.000	

*** $p \leq 0.001$

Farmers determined whether manure was ready to use in the field by its smell, appearance or temperature. Smell and temperature were mentioned more by farmers who had not used manure in the past, whereas appearance was mentioned more by farmers who had used manure (Table 4.56).

Table 4.56 Knowledge amongst previous animal manure users and non-users about how to determine whether manure is well decomposed and ready to use in the field

Method	% positive response			P
	All farmers (n=87)	Previous users (n=67)	Non-users (n=17)	
Smell	64.4	64.2	70.6	0.620
Appearance	48.3	50.7	29.4	0.115
Temperature	32.2	28.4	52.9	0.055
Don't know	13.8	16.4	5.9	0.471

Overall, farmers who had used manure in the past had significantly more knowledge than those who had not. However there were fewer significant differences than for inorganic fertiliser.

4.4.7 Knowledge distribution

Differences in knowledge distribution were most obvious with respect to modern soil fertility practices with farmers who had used agrochemicals in the past knowing significantly more about them than farmers who had not. There were also differences in knowledge distribution about animal manure, but there were fewer significant differences than for the agrochemicals. There were no consistent differences in knowledge distribution for long established and widespread practices such as bush fallowing and traditional aspects of soil fertility management.

4.4.7.1 Gender

Once differences between farmers who had used specific agrochemicals in the past and those that had not had been taken into account, the distribution survey showed that men had more knowledge than women about herbicides and inorganic fertiliser. However, women observed that inorganic fertiliser reduced black ant and termite attack on plantain more frequently than men.

During the administration of the distribution survey the enumerators noticed that women appeared to have less knowledge than men. Overall analysis of the data showed that for many open ended questions, men had provided more responses than women for all topics, and that some of these gender differences in response were significant. However, except for inorganic fertiliser and herbicide, these differences were scattered rather than consistent for particular topics.

The questionnaire responses were analysed for gender differences in response to open ended and multiple choice questions. Whilst multiple choice questions may over-estimate local knowledge, open ended questions could equally well under-estimate it. For each open ended question, the total number of responses given by each respondent was calculated. The mean number of responses for men was compared with the mean number of responses for women for each question (taking into account any differences in previous use of a soil fertility practice). In 28 out of 35 analyses the mean number of responses given to a question was greater for men than for women, and 11 of these results were significant, as opposed to two analyses where women provided significantly more responses than men (Table 4.57). Multiple choice questions were then analysed to determine any gender differences in expected responses. In this case, the number of occurrences of men providing more expected responses than women was equal to the number of occurrences of women providing more expected responses than men (Table 4.58).

Table 4.57 Mean number of responses per open ended question for men and women

Topic	Category of respondent	No. of analyses*	Results of all analyses		No. of questions where there were significant differences ($p \leq 0.05$)	
			m>f	m<f	m>f	m<f
Weeds	All farmers	11	8	3	3	0
Weeds	Farmers perceiving *Chromolaena odorata* easy to control	1	0	1	0	1
Weeds	Farmers perceiving *Chromolaena odorata* difficult to control	1	1	0	0	0
General soil fertility	All farmers	6	6	0	3	0
Inorganic fertiliser	Farmers with experience of use	5	4	1	1	0
Inorganic fertiliser	Farmers without experience of use	4	2	2	0	1
Animal manure	Farmers with experience of use	4	4	0	1	0
Animal manure	Farmers without experience of use	2	2	0	2	0
Cover crops	All farmers	1	1	0	1	0
Total		35	28	7	11	2

* A total of 28 different questions were used. m: mean number of responses per question for men, f: mean number of responses per question for women

Table 4.58 Analysis of gender differences in the expected responses given to multiple choice questions

Topic	Category of respondent	No. of analyses*	Results of all analyses		No. of questions where there were significant differences ($p \leq 0.05$)	
			m>f	m<f	m>f	m<f
Weed species	All farmers	17	8	9	0	1
Weeds – general	All farmers	1	1	0	0	0
Weeds – herbicide use	Farmers without experience of use	2	2	0	0	0
Weeds – herbicide use	Farmers with experience of use	2	2	0	1	0
General soil fertility	All farmers	4	2	2	0	0
Inorganic fertiliser	Farmers without experience of use	6	0	6	0	0
Inorganic fertiliser	Farmers with experience of use	6	2	4	0	1
Animal manure	Farmers without experience of use	3	1	1	0	0
Animal manure	Farmers with experience of use	4	4	0	1	0
Total		45	22	22	2	2

* 34 questions were analysed in total. m>f: indicates that men gave more expected responses than women, m<f indicates that women gave more expected responses than men.

This result indicates that open ended questions were more sensitive to differences in knowledge distribution than multiple choice questions. It also shows that men were more articulate and talkative during the interviews than women, and may also have had more knowledge.

4.4.7.2 Location

Overall there were no obvious and consistent differences in knowledge distribution between the five blocks used in the generalisation survey, or the five field sites used for knowledge

elicitation. However, some differences in knowledge distribution for particular topics or questions were found, and these are summarised here:

- Farmers in the Kumasi block appeared to have more knowledge about herbicides than farmers elsewhere, although farmers in the Obuasi and Asankrangua blocks may have known more about Gramoxone rather than Roundup.
- Farmers from different study sites had knowledge of the influence of tree crop competition for different tree species.
- There were few obvious differences in knowledge about weed species, although more might be expected using a larger sample. There was only one significant difference, with farmers in the Wenchi and Sunyani blocks having significantly more knowledge about *Imperata cylindrica* than those in the other blocks.
- Farmers in the Kumasi and Asankrangua blocks, and cocoa farmers, were significantly more likely to state that burning enhanced the sprouting of cocoyam than farmers in the other blocks.
- Farmers in the Wenchi block were less likely to mention that burning decreased weed growth on the farm.
- Significantly more farmers with experience of fertiliser use in the Sunyani and Wenchi blocks were aware of negative impacts of the use of inorganic fertiliser in the long term.

4.4.7.3 Access to extension

Access to extension did not appear in itself to influence farmers' knowledge. However it was associated with past use of inorganic fertiliser, animal manure and herbicide (Table 4.59). This association was significant for the use of inorganic fertiliser by non vegetable farmers and for women's use of herbicide.

Table 4.59 The influence of extension on previous use of different soil fertility technologies

Technology	Farmer category	Proportion of farmers having tried the technology in the past (%)		p	
		Farmers with some individual contact with extension	Farmers without any individual contact with extension		
Inorganic fertiliser	Vegetable farmers	92.3	88.5	1.000	
Inorganic fertiliser	Non vegetable farmers	65.0	49.5	0.053	*
Herbicide	Men	52.1	40.7	0.239	
Herbicide	Women	36.0	11.5	0.012	**
Manure	Men	85.4	75.4	0.203	
Manure	Women	68.0	54.5	0.237	
Cover crop	All	70.1	70.8	0.918	

** $p \leq 0.01$
* $p \leq 0.05$

4.5 Facilitating the use of local knowledge in research and development in Ghana

One of the problems with local knowledge research has been that little of it has been used for the benefit of local people in developing countries. Local knowledge has been compared to scientific knowledge and used as a means of enhancing overall understanding, but wider application has been more elusive (Joshi *et al.*, in press). One of the reasons for this has been the difficulty in retrieving local knowledge, much of which is in the form of reports, articles and theses. Furthermore, detailed qualitative knowledge is often very descriptive and hence bulky, and context specific. When published in scientific journals only some of the descriptive detail is reported.

The AKT5 methodology used in this research results in an explicit and formal record of the local ecological knowledge on a computer in the form of a knowledge base. This record of knowledge can be easily accessed using the knowledge based systems software so that other research and development professionals and students can easily have access to it.

One of the outputs of this research was the production of five knowledge bases concerning local ecological knowledge of soil fertility. The statements and terms used in the knowledge bases were edited to make them consistent and therefore accessible to other users. They were then organised around relevant topics such as soil fertility management, soil types and weeds, using consistent topic names in each knowledge base. A set of customised tools was written to accompany the knowledge bases to facilitate the retrieval and comparison of knowledge from them (Section 4.1.4). In addition to the knowledge bases and customised tools, a short guide to the software and knowledge bases was produced showing the user how to use the software, demonstrating how to retrieve knowledge from the five knowledge bases, and summarising the main aspects of knowledge (Moss *et al.*, 2001). The guide, software and knowledge base and other associated files were then circulated to research and development professionals in Ghana.

4.6 Discussion

In this section, the local knowledge is discussed taking each soil fertility management topic in turn. The discussion highlights how farmers' knowledge of soil fertility in Ghana compared with local knowledge elsewhere. Gaps in farmers' knowledge are outlined and the distribution of knowledge is discussed. The local knowledge is used to help explain farmers' decision making about the management of natural resources. The appropriateness of some current

agricultural research and dissemination activities are discussed, drawing on the results of the livelihoods analyses in Chapter 3 as well as the local knowledge reported here.

4.6.1 Farmers' understanding of soil properties and nutrient cycling

Farmers held an aggregate concept of soil fertility, associating organic matter with fertile soil and identifying physical as well as chemical properties that influenced crop productivity (Section 4.4.1). An aggregate local perception of soil fertility has been found amongst farmers elsewhere, as has the association of fertility with organic matter and the appreciation of soil physical properties (e.g. Corbeels *et al.*, 2000; Birmingham, 2003; Grossman, 2003; Joshi *et al.*, in press). These aspects of local knowledge indicate that farmers should have no problem appreciating the principles behind the use of technologies which manage soil fertility through the addition or creation of organic matter.

Nevertheless, farmers' knowledge of nutrient cycling and soil processes had limitations, and these were very similar to those found amongst smallholder organic farmers cultivating coffee under shade trees in Mexico, studied by Grossman (2003). Farmers from both countries were able to describe how leaf litter decomposes and forms organic matter (Section 4.4.3.1) but they displayed similar limitations in stating how plants take nutrients up from the soil, and in describing the existence and role of soil organisms. Both sets of farmers had observed the positive role of earthworms in maintaining soil fertility but had little knowledge of any other soil organisms, particularly in Ghana. A few farmers in Ghana knew or had been taught that certain leguminous crops such as cowpea or tree genera such as *Leucaena* and *Gliricidia* were particularly good for the soil, but awareness or understanding of nitrogen fixation was very rare. Similarly in Mexico farmers' limited knowledge of nitrogen fixation had been obtained through training received as organic farmers.

Plant nutrient supply was clearly not farmers' only concern in soil management. Talawar and Rhoades (1998) state that there is rarely a strong relationship between measurable soil fertility and soil preference by local people because soil fertility alone cannot guarantee crop productivity. Although the research area spanned savanna to humid forest zones the ability of the soil to provide moisture to plants was an important property of fertile soil throughout. Year round moisture availability is particularly important for perennial crops such as plantain and cocoa which must withstand a dry season of around four months. Cocoa ideally requires a dry season of no more than three months with rainfall below 100 mm (Mossu, 1992); whereas plantain thrives in areas with evenly distributed rainfall with a minimum of 1 250 mm and the

roots are relatively shallow with 65% of water uptake from the top 30cm of the soil (Norman *et al.*, 1995).

Fertile soils were described by farmers as 'cool' (Section 4.4.1) and farmers' ranking of the productivity of different types of land and soil was strongly influenced by moisture availability (Section 4.4.2.2). Farmers generally preferred black loamy soils and sandy soils with high moisture availability rather than the heavier soils which frequently had higher organic matter content. Seasonally waterlogged soils in valley bottoms were seen as specialised soils only suitable for particular crops, so that despite nutrient levels comparable to other soil types, they were not always ranked highly.

Farmers were also aware of different levels of competition of tree species for soil moisture (Section 4.4.4.2) and both Saunders (2002) and Richards and Asare (1999) found that the affect of trees on soil moisture was a major influence on their selection and management on cocoa farms in southern Ghana. Tree species observed to increase available soil moisture were actively retained to mitigate against the drying effect of the harmattan. Species with a positive influence on soil fertility were also actively retained.

Farmers elsewhere have been aware of relationships between moisture availability and crop productivity. Both the Gourmantché of Burkina Faso, and farmers from south-west Niger evaluate the productivity and suitability of different soil types according to the amount of rainfall they receive and the macro- and micro-topography (Niemeijer and Mazzucato, 2003). Soil moisture availability may be considered more important than nutrient availability where fertility can be addressed by land management.

During this research, farmers used colour and texture as the main means of distinguishing between different soil types. Local classification is usually highly contextual and uses multiple criteria to classify soils. However, amongst different ethnic groups, texture and colour are the most commonly used ways of defining soils, followed by consistency and moisture, and then by organic matter, stoniness, topography, land use, drainage, fertility, productivity, workability, structure, depth and temperature (Barrera-Bassols and Zinck, 2003).

Farmers in the research area did not have a consistent naming system for different soil types. The soil types named by farmers, although broadly similar, differed across locations, and contextual differences were important in explaining farmers' preferences for different soils and their productivity. At Susuanso, red soil was considered more fertile than sandy soil, unlike at the other locations where soil samples were taken. Overall, understanding and

referring to the soil properties recognized and valued by farmers is likely to be more useful than a fixed naming system in communication with farmers, at least in the south of Ghana. Shrestha (2003) came to a similar conclusion when working with farmers in Nepal and emphasised the importance of understanding the local knowledge of the properties and characteristics of soils that underlie their local classification. Payton *et al.* (2003) has also observed that farmers may not always apply the same criteria e.g. colour or texture, to soil classification systematically and different farmers may apply them differently.

Talawar and Rhoades (1998) suggest that the classification of soils may be different, and more complex than that of animals and plants due to the very distinct boundaries which exist between the latter entities which are entirely separate as opposed to the fuzzy boundaries that exist between different soil types. Niemeijer and Mazzucato (2003) argue that correlation between local and scientific taxonomies is often impossible due to conceptual differences in the basis of classification. Local soil classifications usually use visible criteria and put soils into natural categories which take all soil properties into account at once. Scientific classifications often focus on soil genesis or quantitative laboratory analysis and may therefore put soils into separate categories when they are in fact very qualitatively similar.

Farmers appeared to lack knowledge of soil pests and diseases, and of soil acidity. Ants and termites were the most common pests mentioned. Some farmers had observed the aggregate effect of improved soil nutrient status on plantain in conjunction with a decrease in termite and ant attacks, but other than this pests and diseases were rarely mentioned. Yvon (1996), who interviewed vegetable farmers in the Brong Ahafo region, also confirms farmers' lack of awareness of nematodes which are a major pest of tomato. Bentley (1994) has observed that the life forms, life cycles and feeding habits of many plant pests and diseases are difficult to observe, and that although farmers in Honduras have many words to describe social wasps, and understand well the life cycle of bees, they lack knowledge of the life cycles of other insects, of entomopathogens, parasitoids and insect predation. Lack of local knowledge about plant pests and diseases has been observed in Nepal and elsewhere, although filling in gaps in farmers' knowledge has been successful in stimulating farmers' experimentation with non-chemical pest control measures (Gurung, 2003; Bentley and Thiele, 1999).

Farmers were sometimes aware of their inability to explain differences in crop performance. At Oda, farmers decided on the best location for new cocoa farms by referring to the existing performance of cocoa already in the area. They had noted that in some areas, despite the presence of good forest growth, cocoa did poorly once the natural vegetation was removed. Some farmers suggested that shallow soil with rock underneath might inhibit the long-term

performance of cocoa on upland, but they had no explanation for differences in cocoa performance on deep lowland alluvial soils. Soil tests by the Oda Kotoamso Community Agroforestry Project revealed that these soils were probably too acidic for cocoa being below pH 4. Landon (1991) gives pH 4.5 as a minimum for satisfactory cocoa yield with pH 6.0 – 7.5 as optimum.

4.6.2 Integrating trees with crops

This research has confirmed that farmers were aware of the beneficial role of trees in maintaining the productivity of the soil (Section 4.4.3.2; 4.4.4). They valued trees for providing soil cover and contributing to the recycling of organic matter. They were aware of differences between species in terms of their competition with crops for soil moisture, and this knowledge contributed to their decision making about which trees to retain. Research and development work attempting to integrate trees with crops on farms in southern Ghana should take this knowledge into account. Further local knowledge from southern Ghana about the interactions between trees and crops is reported in Saunders (2002) and Amanor (1996). Tree species which farmers are unfamiliar with can be presented to them in terms of attributes, such as rooting depth, which will enable them to weigh up the opportunities and constraints of each species. Farmers will then be able to make their own choice of tree species based on their own assessments of the potential trade-offs between opportunities and constraints.

Despite knowledge of the positive impact of trees in general, and some species in particular, Amanor (1996) reports that farmers found that integrating trees with crops was problematic, even on cocoa farms. MOFA advice is to retain 12 – 20 trees per hectare (Saunders, 2002). Some farmers at Oda, planting hybrid cocoa said they were aiming to remove all trees over time. Although cocoa may yield well initially without shade, its life span may be reduced if growing conditions are not ideal, which is the case in much of the Western region where there is annual moisture stress and soils are acidic.

Saunders (2002) identified potential parallels between farmers' understanding of the influence of trees on soil moisture and understanding in the scientific literature. Trees which farmers claimed brought moisture to the surface from deep within the soil may have been operating through hydraulic lift. Hydraulic lift occurs where the root system draws moisture from lower soil layers and redistributes it to shallower drier soil layers, particularly at night when water potential decreases (Caldwell *et al.*, 1998). Neighbouring plants have been demonstrated to use water obtained in this way. Hydraulic lift has been demonstrated in dry tropical forests and is thought to be associated with leaf phenology and tree size with smaller trees

independent of species, and trees that loose their leaves only briefly in the dry season, using more water from deep soil layers than other trees (Meinzer, 1999).

Saunders (2002) suggests that water that farmers observed dripping from the leaves of trees may have been the result of guttation. Fisher *et al.* (1997) observed guttation and xylem sap exudation attributed to root pressure in 15 out of 109 tropical vine and woody species observed, with the majority of sap lost in the pre-dawn hours. There are two other alternative explanations for farmers' observations. Walker (1962) observes that although quantitative data are lacking, dew appears to be an important source of moisture to plants, especially in the hill ranges which are in cloud most nights of the year and where copious amongst of dew can be seen dripping off the trees. Early morning mists also occur in valley bottoms in the forest and savanna zones and dew may remain on the vegetation until 10.00. Under shade forest topsoils may remain moist with dew the whole day. Although the research was carried out in lowland rather than hilly areas of Ghana, deposition of dew by tree species that retain their leaves for part of the dry season may relieve moisture stress in crop plants. Barradas and Glez-Medellín (1999) suggest that dew may enhance the survival of some species in dry tropical forests during the dry season. Species which possess leaf phenology asynchronous with most other species may benefit from a reduction in transpiration rates during the morning. A third explanation for farmers' observations is that moisture falling from the leaves of some trees was the effect of sap sucking insects. Farmers in Kenya knew the tree *Lannea stuhlmannii* as the 'rain tree' because when large numbers of leaf hoppers (family Cicadoidea) collected on it in the dry season the tree glistened with moisture and could produce a raining effect (Kiptot, 1996). Some farmers at Oda had observed that *wawa* (*Triplochiton scleroxylon)* dripped a sticky exudate in the dry season which had a negative impact on the growth of crops underneath it. However more generally, farmers did not make any association between sap sucking insects and moisture exudation from trees.

4.6.3 Farming without fire

Local knowledge shed light on farmer decision making in the use of fire in land preparation. There has been interest in Ghana in farming without the use of fire for many years and care in the use of fire has been particularly heavily promoted since the bush fires of 1983. Using vegetative biomass as mulch has been seen as one way of developing agricultural practices that reduce the use of fire and conserve soil nutrients. Research has been carried out in Ghana since the late 1960s and in the 1990s was concentrated at the Crop Research Institute in

Kumasi in conjunction with the Ghana Grains Development Project[20] (Ekboir, 2002). A strong extension programme for the promotion of the technology by the Ministry of Agriculture, Sasakawa Global 2000 and Monsanto has existed in Ghana since 1993, with the main extension focus on large demonstration plots. The extension message has been aimed at maize and involved the use of certified seed, fertiliser at planting and as a top dressing, pre-planting herbicide weed control, either manual or chemical in crop weed control and harvesting methods which leave crop residues in the field.

This research found little evidence of farmers using vegetation as mulch rather than burning or of widespread use of herbicides at the field sites visited and surveyed (Section 4.2.1). The local knowledge elicited from farmers has added to our understanding of why they rarely opt not to burn (Section 4.4.3.5). Farmers were fully aware that rotting vegetation adds to soil organic matter. However the most important reason for burning was practical. Large quantities of biomass could severely hamper farm work and damage certain crops (particularly maize). Farmers had also observed that cocoyam did not sprout, and at Oda that cassava did not grow if land was not burnt. These practical observations that lie behind the use of fire have been known for some time for both forest and savanna areas (Nye and Greenland, 1960).

In an evaluation of the adoption of the herbicide/mulch package in villages where it was promoted using demonstration plots, Ekboir *et al.* (2002) estimate that in 2000, 100 000 farmers were using the technology in the forest, transition and guinea savanna zones of Ghana on 45 000 ha of land. Lack of evidence for the use of this technology elsewhere is probably because the evaluation focused on villages which had hosted demonstration plots, and because extension agents elsewhere were not actively promoting herbicides as they considered them too expensive for smallholder farmers, although they did actively encourage farmers to obtain advice from them before using herbicide on their fields for the first time.

Ekboir *et al.*'s (2002) evaluation provides some valuable pointers about the appropriateness of the technology to farmers belonging to different social categories and the conditions under which adoption of the technology is likely to be successful. The results of the evaluation, some of which are summarised in Box 4.1, in conjunction with what has been learnt about

[20] In addition to national research partners the Ghana Grains Development Project involved two international research organizations – the International Institute of Tropical Agriculture (IITA) and the International Maize and Wheat Improvement Centre (CIMMYT) and was funded by the Canadian International Development Agency (CIDA) and the Government of Ghana.

rural livelihoods in Chapter 3 and farmers' knowledge in this chapter, suggest that attributes of farmers that make them more likely to adopt the package were:

- strong dependence on agriculture as opposed to other activities,
- ability to use cash to pay for weed management,
- willingness to forgo maize intercrops,
- secure tenure for a number of years (providing farmers with greater savings on land preparation costs) and
- preference for purchase of fertiliser over moving to another plot of land.

Furthermore, a strong extension input appeared to be necessary for adoption including one to one interaction with an extension agent or another farmer for herbicide application. This is probably because the herbicide/mulch technology package is complex and involves the introduction of a number of practices which are new to farmers. Furthermore, herbicide use is a technology requiring a high level of precision to be effective. Excellent results from the first field trial were associated with adoption and may be a result of the high level of extension support provided.

Factors influencing farmers' adoption of a herbicide/mulch package in the forest, transition and savanna zones of Ghana (Ekboir *et al.*, 2002)

Adoption was stimulated by a strong extension input. Adopters had more interaction with extension agents than those who had not tried the package or who had abandoned it. Over 70 % had learned about the package from a research or extension agent and received training, and the majority were helped on their field in the first trial by an extension agent or neighbour.

The majority of adopters had excellent results from their first trial as opposed to only 39 % of abandoners. Farmers who had tried the package were on average more innovative and resourceful than those who hadn't and also had a greater number of years of farming experience. Women farmers appeared to be less innovative (21 % of women said they had tried new things in their fields in comparison with 43 % of men). One reason for this may be that women are more likely to work at home or have other employment (usually trading) so that they spend less time in their fields than men.

The cost of herbicide appeared to be a major problem for those who had not adopted the package. Overall, planting and plant survival was the most important problem for those who had adopted it. 86 % of farmers used the package to control grass weeds as opposed to only 14 % controlling broad leaved weeds.

Most adopters used fertiliser in addition to the herbicide/mulch package. Researchers recommended increasing the plant density of maize fields which reduces the possibility for intercropping. Farmers who had not used the package were more likely to intercrop.

The main impacts of the technology were reduced cash and labour investment and higher yields. Reduction in labour use was predominantly for male family labour for weeding, planting and land preparation. In addition to a reduction in man days or cash outlay on labour, labour was also less physically demanding. Maize yields of adopters were calculated as 16 % higher than yields of abandoners and 48 % higher than farmers who had never tried the technology. Herbicide/mulch plots showed less yield reduction in dry years than conventionally managed plots

Box 4.1Farmers' adoption of herbicide/mulch farming in Ghana

Higher levels of adoption of the herbicide/mulch technology amongst male rather than female farmers can be explained by differences in livelihoods and access to resources that were presented in Chapter 3. Men are more likely than women to grow maize predominantly for cash. They are therefore more likely to monocrop, and have more incentive to invest cash in cultivation. Men also have better access to cash than women. Women would usually hire male labour to spray agro-chemicals, and have less time to invest in a complex technology package. They also have less contact with the extension services. These factors may deter, but not prevent them, from trying or adopting the technology. Where women rely on hired male labour for weeding and land preparation they could benefit from reduced expenditure.

Ekboir *et al.* (2002) state that 86 % of farmers used the package to control grass weeds but does not give any further information about the agro-ecological conditions and land use patterns for which the technology would be most appropriate. However, adoption of the

package to control grass weeds would be consistent with findings concerning livelihoods and local knowledge. The cost of manual labour to control weeds that the herbicide would replace is likely to vary greatly according to weed ecology and be higher for grass than for broadleaved weeds so that herbicide use becomes more economical on grass weeds. Furthermore, planting through cleared grasses is more feasible than planting through woody plant debris, and grasses are less likely to damage young maize plants. Grass weeds are more prevalent in the guinea savanna, and in intensively cropped parts of the transition and forest zones. This suggests that in the transition and forest zones the technology is most appropriate for farmers with limited access to land. Farmers sharecropping and renting land for maize had adopted the technology. Although use over consecutive years brings the highest returns to investment, the majority of farmers observed benefits from the technology after only one season. Furthermore, the technology does not improve land productivity, or in any other way appear to prompt or challenge landowners to take land back from their tenants.

4.6.4 Inorganic fertiliser

General knowledge of the potential of inorganic fertiliser for increasing crop production was common knowledge amongst farmers (Section 4.4.5). However more detailed knowledge of different types of fertiliser, and practical aspects of fertiliser use was limited to farmers who had used it in the past. This finding does not necessarily mean that farmers are not using inorganic fertiliser due to lack of knowledge. Farmers considered that application to root crops such as cassava produced tubers which were of low quality for the staple dish - *fufu*. For cash crops such as maize, the profitability of inorganic fertiliser under farmers' conditions of imperfect weed management, seasonally fluctuating maize prices, multiple and competing cash crop interests and low access to cash were probably greater factors in decision making than their knowledge. More detailed knowledge about fertiliser use held within the community may be sought only when farmers need it.

Potential negative consequences of sole use of inorganic fertiliser were unknown to the majority of farmers. However, there was an indication of increasing awareness that long term use could alter the soil, particularly amongst vegetable farmers, farmers from the north and farmers in the Sunyani and Wenchi blocks. Vegetable farmers may have observed changes in the soil associated with continuous cropping and inorganic fertiliser use as they are more likely than other farmers to have used inorganic fertiliser on a regular basis. It is likely that other farmers have been told that fertiliser is bad for the soil, as many of the extension agents interviewed from the Sunyani and Wenchi blocks stated that they had been delivering this message to farmers. There were also a number of organisations promoting alternative

management of soil fertility such as GOAN and the Sedentary Farming Systems Project in this area.

4.6.5 Animal manure

Although most farmers were aware that animal manure could be used to fertilise the soil their knowledge did not appear to be well developed, with large numbers of farmers who had used animal manure in the past believing that it could not scorch crops and that it could be used fresh without waiting for it to decompose (Section 4.4.6). Few farmers are likely to have used manure in the past on a regular basis and it is likely that they have simply not acquired this knowledge. The potential extent of the use of animal manure is currently limited by the quantities available. Zimmermann (2001) found that 43% of farmers in the Kumasi, Obuasi and Asankrangua blocks did not keep any livestock. Furthermore, Asante *et al.*, (1999) found that farmers do not consider it worthwhile to collect manure from their own animals and carry it to farms which are often far away and most farmers dispose of animal droppings on the village refuse dump. In addition to the lack of livestock, settlement and farming patterns may limit experimentation with manure and organic household refuse. Settlements in the areas visited tended to be nuclear with dwellings built very close together – backyard farms were limited to the outskirts of the settlement area where land was still available. Livestock damage also prevented farmers from cultivating fields very close to the settlement.

There is greater potential for use of manure in peri-urban areas where livestock numbers are higher. However, even here use is currently limited. Zimmermann (2001) found that only 6% of fields in peri-urban villages were fertilised with poultry manure and that these were mostly commercial vegetables. Greater knowledge may stimulate farmers' interest in the use of manure where it is easily available and leads to productivity increases. Currently farmers do not perceive manure as readily available when several journeys are required to a poultry farm to find out whether it is currently available (involving farmers' time and the cost of transport) and when fields are distant from motorable roads. Development of links between poultry farms and farmers wanting to use poultry manure in conjunction with the promotion of the use of poultry manure amongst farmers might result in greater use of manure. Although currently it is estimated that 67 % of poultry manure produced in peri-urban Kumasi is used, the disposal of the remainder is said to be a problem (Brook and Davila, 2000). Drechsel *et al.* (2000) estimates that 54 000 t dry matter goat and sheep manure, 12 000 t pig manure and 34 000 t poultry manure are produced annually in the peri-urban area. Very little cattle, goat, sheep or pig manure is used, although the ruminants are kraaled at night and pigs are fully stall fed.

4.6.6 Weed management

Farmers' agro-ecological knowledge explained the rationale behind the different ways in which weed residues were used that was not always obvious from observation alone (Section 4.4.3.2). Spreading of slashed weeds evenly over the farm appeared to be the most common practice and added organic matter to the soil and provided soil cover. Heaping weeds around the base of cassava, cocoyam or other crops was done to protect the tubers from mammalian pests such as grasscutters (*Thryonomys swinderianus*) and to retain soil moisture and add organic matter to the soil in the vicinity of the crop. Heaping slashed weeds at the side of the farm was done with certain species to prevent them from resprouting from fragments left on the soil, to make it easier to move around the farm or else to prevent termites and other pests from hiding in the weed cover.

Farmers at all field sites linked decline in soil productivity with increased weed problems. Shorter fallow periods were also directly associated with more weeds. Weed growth was faster due to the greater competitive ability of weeds under poorer soil conditions, and there were changes in the weed ecology on cultivated land. Nye and Greenland (1960) state that it is difficult to separate the influence of weeds and declining soil fertility on falling crop yields. An increase in weeding requirements is often the primary reason for abandoning land to fallow as opening up new land may require less labour than weeding, and requires labour during the dry season which is a relatively slack period of the year.

Farmers were clearly aware of competition between weeds and crops, the over-riding importance of timely weeding, and the implications for crop yield (Section 4.4.3.3). Nevertheless, the amount of weeding that farmers actually did was often less than what they considered ideal. Farmers at Subriso presently managed to weed maize only once rather than the two or three times that they had stated (Obiri-Darko, 2003 pers. comm.), and the labour constraint for weeding was clearly visible in other cropping adaptations such as the planting of cocoa at closer than the recommended spacing in order to suppress weed growth through early canopy closure. Socio-economic considerations clearly conditioned farmer decision making and action on weeding despite adequate agro-ecological knowledge of weed crop competition.

In Malawi Orr *et al.* (2002) also found constraints to weed management. Farmers' weeding of maize fields was based on a series of contingent decisions in response to rainfall, termites, fertiliser use and labour supply. Socio-economic constraints leading to late weeding were a result of household labour shortage due to illness, old age or competing time demands

coupled with farmers' inability to hire labour. A similar study to Orr *et al.* (2002) in Ghana would lead to a better understanding of farmers' weeding decisions. Current weed management may already be best practise given current socio-economic constraints. Designing future recommendations without an effective understanding of farmer decision making behaviour may not produce relevant results, so that soil fertility or weeding recommendations are not adopted by farmers. Particular attention should be given to the different social categories of farmer who are likely to have different socio-economic constraints, and hence display different decision making behaviour. Weeding may be more of a constraint for female farmers than male farmers. Female farmers have more demands on their time than men due to their domestic responsibilities and role as carers. Furthermore, in cocoa growing areas wives typically take care of food crops whereas husbands tend older cocoa farms where weeding requirements are lower. Overall weeds are likely to be more of a concern to farmers with less access to good land, and to farmers whose own labour is limited and have limited cash to hire labour.

4.6.7 Differing opinions about *Chromolaena odorata*

The dominant fallow species, *Chromolaena odorata* is a widespread invasive weed of tropical and sub-tropical areas of Asia and Africa (Cruttwell, 1988b). It originated in the Americas where it is host to a large complex of insects and diseases which are thought to reduce its aggressiveness so that it is not considered an important or significant weed in its countries of origin (Cruttwell, 1988a). However, elsewhere it is seen as an invasive exotic and a number of countries have been experimenting with biological control including Ghana, Nigeria, Côte d'Ivoire, South Africa, India, Sri Lanka, Indonesia and the Philippines (Muniappan, 2002).

C. odorata has been found in Ghana since 1969 and is well established throughout the forest and transition zones (Braimah and Timbilla, 2002). Biological control is being carried out using the moth *Pareuchaetes pseudoinsulata* which defoliates the leaves of the plant. It was introduced into the Kumasi area in 1991 and is now thought to cover two thirds of the area where *C. odorata* is found, extending as far north as Sunyani, as far East as the Volta Lake and as far West as Bibiani. Monitoring surveys have had limited resources, but so far the moth does not appear to occur in the transition zone further north of Sunyani or in the most heavily forested parts of the country to the west of Sunyani and Bibiani, although it is well established throughout the Ashanti region. Despite the good establishment of the moth, it seems to have had limited success so far in controlling *C. odorata*. The plant retains much of its energy reserves in its stems and roots but the insect only defoliates the leaves of the plant which then regrow so that repeated attacks are necessary to suppress it. As *C. odorata* flowers

with the onset of the dry season, and because the insect is susceptible to moisture stress, it has little effect on the prolific flowering and seed-set that enables the plant to re-colonize fields. It is therefore thought that other natural enemies that attack the stems and roots will have to be introduced in conjunction with *P. pseudoinsulata* in order to adequately suppress the weed (Braimah and Timbilla, 2002).

Biological control of *C. odorata* in West Africa appears, so far, to have been conducted with little research into the consequences of successful suppression of the weed. Both positive and negative qualities of the weed have been acknowledged. It can suppress the regeneration of forest trees and is a major agricultural weed. Its abundant leaf litter is considered a fire hazard and it is associated with the variegated grasshopper, *Zonocerus variegates* – a pest of cassava. On the positive side it has medicinal properties that are used by local people and it is able to recycle soil nutrients through its rapid biomass accumulation and abundant litter fall (Timbilla and Braimah, 1991). However there has been very little research to adequately quantify or substantiate these claims or the impact of *C. odorata* on the environment, the forestry or the agricultural sectors.

This research has shown that Ghanaian farmers have both positive and negative opinions about the plant and does not indicate that they would like to eliminate it (Section 4.4.3.2). They valued *C. odorata* for its ability to restore soil fertility on the fallow, as do farmers elsewhere including Laos (Roder *et al.* 1996) and Benin (Yehouenou, 1996). Their negative opinions of the plant are a result of the difficulty they have in controlling it as a weed of crop land. Unfortunately, the rapid growth that makes *C. odorata* so successful at accumulating biomass, when combined with its abundant seed dispersal, and regrowth when slashed, also make it very weedy. Although some farmers have noted that *C. odorata* inhibits tree regeneration on the fallow, they have also noted that it is successful in competing and succeeding grass species such as *Panicum maximum* which have less value as soil fertility regenerators, and are even more difficult to manage and control as weeds of crop land than *C. odorata*.

With regards to soil fertility and biodiversity, the key question is - what plants would replace (or partially replace) *C. odorata* should its suppression be successful? *C. odorata* is associated with disturbed land and open areas, and is an integral part of rural livelihoods in the forest and transition zones of Ghana. In the context of declining length of fallows, increasing land scarcity, and labour shortages, how would changes in fallow vegetation and weed species influence the livelihoods of smallholder farmers. Would the changes result in fallows that were easier or more difficult to clear? Would the fallow vegetation contribute as much to soil

organic matter as *C. odorata* does over a similar time period? Would the plant species associated with an increase in biodiversity be more or less useful plants than current fallow vegetation? Would suppressing *C. odorata* necessarily result in more rapid succession to secondary forest? It has been over thirty years since *C. odorata* first appeared in Ghana and the pressure on forest and agricultural land has increased and the ecological balance of the natural vegetation may have changed. Tree density throughout the forest and transition zones has probabley decreased resulting in less root and seed stock available for forest regeneration. At the same time, the root and seed stock of non-woody weedy plants may have increased. Fallows are shorter and are less likely to ever become secondary forest before they are cultivated again.

Research needs to be carried out to determine what ecological changes would occur with greater suppression of *C. odorata*. This research needs to take into account the different agro-ecological conditions found in different parts of Ghana with a minimum consideration of quantity and distribution of rainfall, agricultural land use patterns and the availability of root and seed stock from which natural fallows would regenerate. The desirability of *C. odorata* might be different in different locations. Where land is cropped frequently with annual crops, tree cover is sparse and grasses are becoming more dominant on fallow land, such as in peri-urban Kumasi and at Subriso and Yabraso, *C. odorata* could be a desirable plant to retain in the absence of other species capable of restoring soil organic matter as efficiently. On the other hand, where tree cover is still high, rainfall is plentiful, and grasses rarely dominate fallow land for long, such as at Oda, *C. odorata* might be an undesirable species which it would be better to replace by other trees and shrubs.

The little research that has been completed so far on the effects of reduced *C. odorata* on fallow land seems to show that resulting weeds are not necessarily more favourable. Ikuenobe and Anoliefo (2003) found that a modified fallow in Nigeria with the *C. odorata* removed promoted grass weeds during cropping whereas fallows of *C. odorata* and *Mucuna pruriens* both promoted broad leaved weeds (mainly *Ageratum conyzoides*, *Tridax procumbens* and *Phyllanthus amarus*) and resulted in higher maize grain yields. The aggressive growth of *C. odorata* was thought to be responsible for its ability to shade out other weeds during the fallow. Herren-Gemmill (1991) compared a tractor cleared and cultivated field and a traditionally cultivated field. On the tractor cleared field *C. odorata* cover was less dense and replaced by grass and herbaceous weeds rather than other woody species. In the traditionally cultivated field *C. odorata* thicket formation was more rapid than on the mechanically tilled site where it appeared to be much retarded. Weise *et al.* (2002) report that when *C. odorata* was manually removed from fallows in Cameroon other more problematic weeds such as *Sida*

spp., Stachytarpheta cayennensis and Euphorbia heterophylla increased substantially. Maize yield was higher after a *Pueraria phaseoloides* fallow than after *C. odorata* but there was no yield advantage for cassava and in the fallow where *C. odorata* was removed cassava yield was lowest.

Field studies in Ghana in 1998 reported by Timbilla and Braimoh (2002) found that where *Pareuchaetes pseudoinsulata* had established *C. odorata* was reduced from a mean of 85.0% of infested fields to 36.4%. They estimated that grasses had increased from 2.0% to 13.0%, that other broad leafed plants had increased from 24.2% to 39.4% and that plant diversity had increased from three species m^{-2} to six. However the species promoted by the suppression of *C. odorata* are not reported so that no judgement is possible on whether these are more or less favourable. Future studies of the changing ecology that might result from the suppression of *C. odorata* could augment the knowledge of weed scientists with local knowledge recorded and made accessible using methods such as those used in this research to evaluate what impact ecological changes would have on local livelihoods and whether it would be positive or negative.

Other research in Ghana has shown that *C. odorata* obstructs natural forest regeneration although forest succession does succeed *C. odorata* on farmers' land. Honu and Dang (2002) found a high density of naturally occurring tree species under a densely woven canopy of *C. odorata* in a forest reserve site in Ghana which had been invaded by *C. odorata* following fire damage 15 years earlier and which was bounded by natural forest on two sides. Removal of *C. odorata* had a very positive influence on tree seedling survival and growth (Honu and Dang, 2000). In contrast to the 15 years during which *C. odorata* presumably dominated this disturbed forest, farmers interviewed in this study claimed that the dominance of *C. odorata* decreased on their fallow lands after five or six years and that after eight to ten years all undergrowth had died leading to secondary forest succession. This suggests that some form of secondary forest succession can follow *C. odorata* thickets. However farmers' management practices which preserve tree root stock in the soil and sprouting stumps may influence this and farmers did not say what role coppiced trees, as opposed to tree seedlings, had in forest succession on fallow land. The extent to which *C. odorata* arrests secondary forest succession may depend on management practices or the level of disturbance of the soil and vegetation.

4.6.8 Changes in cropping and soil management

It is often expected that population pressure leading to decreasing length of fallows and hence declining soil fertility will lead to changes in agricultural practices and the intensification and

sedentarisation of agriculture. Tiffen *et al.* (1994) and Harris (1996) described agricultural changes in Kenya and Nigeria. Padoch *et al.* (1998) has illustrated how apparent agricultural decline may mask less visible processes of agricultural change and transformation such as the conversion of swidden cultivation to irrigated rice in Borneo. Iskandar (2000) has reported how isolated and traditional Baduy communities have integrated *Paraserianthes (Albizia) falcataria* into four year fallows for upland rice – a practice both economically and culturally viable as well as contributing to soil fertility.

The crops grown by farmers in the forest and transition areas of Ghana have certainly changed over the last 50 years, although changes have taken place differently in different areas and markets have been important influences (Section 3.3.2). Amanor (1993; 1994) has described instances of indigenous experimentation with improved fallows in the Eastern region in response to reduced fallow periods and changing ecological conditions. However, only a few examples of this type of experimentation were observed during the present research work or have been reported by other authors. One reason for this may be the differing socio-economic and ecological conditions of the study areas. In peri-urban Kumasi where land shortage was most acute, there may have been more opportunities for off-farm employment than in the Eastern region. In the Wenchi area, where grass species are common on the fallow, population density is still fairly low. Uneven pressure on land within a single village (or larger area) also needs to be recognised. There is more pressure on land types in shortest supply, and different people have differing levels of access to fertile land. Land in shortest supply tends to be lowland areas suitable for rice or dry season vegetables. This land is often rented out for short periods and farmers use inorganic fertiliser. On other land there is a general trend whereby those with least access to fertile land for annuals and biannuals also have shortest and least secure tenure making it difficult for them to invest in soil fertility in the medium to long term. This is not the case for tree crops which are associated with secure tenure.

4.6.9 Distribution of knowledge

Local knowledge research is beginning to suggest where farmers' knowledge is most highly developed, across wide geographical areas and between farmers within the same community. Geographically, it seems that knowledge formed through observation and experimentation is most highly developed in areas where farmers have a high level of dependence on natural resources and where knowledge is required to effectively exploit them (Sinclair and Walker, 1999). In Sri Lanka, under relatively benign environmental conditions, farmers cultivate multi-storey tree gardens to supplement staple paddy rice production. Farmers' knowledge about interactions between species in these gardens is less developed than the knowledge of

farmers managing fodder trees on crop terraces in Nepal where impacts of trees on crop and animal production are critical (Joshi and Sinclair, 1997). Within Nepal, farmers from communities which have less dependence on on-farm tree fodder resources also have less knowledge than farmers in nearby communities with greater dependence on this resource (Joshi, 1997).

Differences in knowledge distribution in this research were most apparent for particular soil fertility practices between farmers who had used the practice in the past, and those who had not. These differences were more consistent for inorganic fertiliser and herbicide than for animal manure. Farmers were less likely to have used animal manure on a regular basis, than inorganic fertiliser, and this probably accounts for the comparatively greater levels of knowledge for inorganic fertiliser and the less consistent differences in knowledge between farmers who had used manure in the past and those who had not.

There were no differences in knowledge between previous users and non users of cover crops (Section 4.4.3.6). Few farmers had used a legume principally for soil cover and nutrient cycling but the ecological role of soil cover was understood and used as an ecological principle in farmer decision making. Many of farmers' descriptions of cover crop cultivation were of crops cultivated primarily for human food which sometimes meant compromising on soil cover. However more knowledge of traditional niches for 'cover crops' in farmers' cropping practices may be of interest to researchers in Ghana.

4.6.9.1 Gender differences

Men had more detailed knowledge about inorganic fertiliser and herbicide than women. Use of agro-chemicals was associated with men more than women, both because men cultivated more commercially orientated crops than women, and because application of agro-chemicals, particularly pesticide, is a task carried out by men (Section 3.4.3.4). Men may therefore have greater interest in agro-chemicals (whether they have used them or not), and where they have used them, they will probably have used them on a greater number of occasions than women.

Men provided more responses to open ended questions than women, although the level of responses to multiple choice questions for men and women was very similar. Men may therefore have had more knowledge than women in general and this may be because they are able to devote more time and attention to farming than women. Differences in knowledge associated with differing levels of interest in, and experience of, particular aspects of natural resource management have been found elsewhere between different social groups within a community. Women in Nepal appeared to know more than men about some aspects of tree

crop interactions and tree fodder due to the different farm tasks that they carried out (Joshi, 1997). In Côte d'Ivoire, Birmingham (2003) found that amongst the Bété, young adults who were generally more educated and had led a more urbanised lifestyle, had less interest in farming, and consequently had less knowledge of soils than older adults. These young Bété also appeared to have less knowledge than young Senufo, who lived in a different agro-ecological area and were less educated and urbanised.

Nevertheless women are frequently less articulate than men. Saunder's (2002) study of cocoa shade tree properties in Ghana found that women had less detailed knowledge than men about individual tree species but also observed that women were less confident in expressing their opinions and ideas, even in a single sex environment, although this was not linked to a clear lack of knowledge. Greater articulateness amongst men has also been found by Birmingham, (2003) for knowledge of soil types in Côte d'Ivoire and by Joshi (1997) for knowledge of tree fodder in Nepal. Lower levels of female education, and cultures and societies that discourage women's participation in public life may be responsible for this.

4.6.9.2 Location differences

Some of the observed differences in knowledge distribution between locations could be explained in terms of agro-ecology. However, farmers' personal farming experience also clearly contributed to these differences. Farmers in the Kumasi block had more knowledge than other farmers about Roundup, which is a post-emergence systemic herbicide and therefore capable of prolonged weed suppression and suitable for use in clearing land dominated by *Panicum maximum*. Farmers in the Obuasi and Asankrangua blocks may have been more familiar with Gramoxone which kills foliage on contact and is therefore suitable for use on tree crop plantations. Less frequent observation that burning decreased weed growth in the Wenchi block may be due to the greater prevalence of grasses in that block. More knowledge about *Imperata cylindrica* in the Wenchi and Sunyani blocks is consistent with the greater prevalence of the weed in drier parts of Ghana. Other significant differences about weed species may have been absent due to the relatively small sample size and the use of multiple choice questions which did not give farmers the opportunity to express their knowledge about the weed species most prevalent in their area. More precise characterisation of villages according to land use and agro-ecology, rather than the very broad block designation may also have picked up more differences in knowledge.

Farmers at different field sites expressed knowledge about different tree species. However, Saunders (2002) found that knowledge of different tree species was limited by a farmer's experience with that species and knowledge of a single species could differ even in one

village due to individual farmers' experience with that tree. Nevertheless, Saunders' (2002) found a high level of consistency between two villages in the Atwima district for farmers' ranking of eight species according to their moisture usage. There was greater agreement between the two villages for species which had the strongest effect than for mid rank species. Hence although there were differences in individual levels of knowledge depending on a farmer's experience, there was overall agreement about specific tree species, particularly for those species which had the largest influence on soil moisture.

4.6.9.3 Access to extension

Differences in knowledge distribution were more strongly associated with whether farmers had used a technology in the past or not, than with access to extension. This may be because farmers do not either retain, or seek out detailed knowledge about new technologies until they need it.

However, previous use of inorganic fertiliser, animal manure and herbicide was associated with greater access to extension, particularly amongst categories of farmers where use of the technology was less expected (Section 4.4.7.3). Women who had some contact with extension were significantly more likely to have used herbicide in the past, and non-vegetable growers with contact with extension were significantly more likely to have used inorganic fertiliser. This positive association suggests that extension has a positive impact on whether or not farmers have tried a technology. However, only 44 % of farmers had any individual contact with an extension agent throughout the year, and women were particularly disadvantaged with only 24 % seeing an extension agent. Furthermore, limited soil fertility extension has been carried out as extension messages have focused more on other aspects of crop production.

4.7 Conclusions

The local knowledge research showed that farmers in the humid and sub-humid areas of Ghana have knowledge of soil fertility management which they use in decision making about natural resource management. Finding ways of incorporating this knowledge into the agricultural research process may enhance the production of technologies which are appropriate to farmers' circumstances. In this section, it is suggested that stronger on-farm research, where farmers play a lead role in technology development, could be effective in mobilising locally relevant agro-ecological knowledge for the development of complex technologies. Local knowledge research also showed that although *Chromolaena odorata* is a fast growing weed that is difficult to control on cropped land, it is valued by farmers for its role in soil fertility regeneration on fallow land. The way in which attempts to biologically control *Chromolaena odorata* have been carried out suggest that environmental decisions are

made without sufficient consideration of their consequences for smallholder farmers whose livelihoods depend on them. The research also found that the distribution of agro-ecological knowledge amongst farmers was associated with their past experience of particular technologies. Although contact with the extension services did not have a significant influence on farmers' knowledge amongst the surveyed farmers, it did have some impact on whether or not they had tried some soil fertility management practices.

Using local knowledge in soil fertility research and dissemination in Ghana

This research showed that farmers in southern Ghana had agro-ecological knowledge about soil fertility and that they were able to articulate it. Table 4.60 summarises how ecological knowledge contributed to farmers' decision making and partially explained their behaviour about the management of natural resources. Farmers' knowledge of the attributes of different weed species, local pest problems and the value of plant residues for providing soil cover and contributing to organic matter explained their choices in the disposal of weed residues.

Table 4.60 Implications of aspects of farmers' knowledge for their decision making behaviour

Area of knowledge	Contribution to decision making
Competitive effect of different tree species for soil moisture.	Contributed to decision making about which trees to retain as shade on cocoa farms. Other factors, such as ability to remove very large trees and expectations of timber contractors also influenced decision making.
Formation of organic matter from decomposing vegetation cleared from the fallow. Influence of burning on subsequent crop growth.	The need to clear large quantities of vegetation from the farm was of overwhelming importance in decision making about whether to burn vegetation from the cleared fallow. This vegetation hampered farm work and could damage some crops.
Attributes of different weed species, local pest problems and the value of vegetation for covering the soil and contributing to organic matter.	Local knowledge explained decision making about the use of weed residues.
Weed ecology and weed crop competition.	Farmers' actions were not in accordance with the agro-ecological knowledge that they expressed. Labour shortages constrained weed management despite knowledge of weed crop competition.

However ecological knowledge was not the only influence on decision making, and other factors also contributed to farmers' behaviour. This was the case with decision making about which trees to retain as shade on cocoa farms, and on farmers' decisions about burning or mulching during land preparation. Sometimes farmers possessed agro-ecological knowledge but did not appear to be using it in decision making and their actions were not at all explained by their knowledge. This was the case with farmers' knowledge of weed management - although they were aware of the effect of weed crop competition and of how to reduce it, they did not act on it in practice.

Evaluation of local knowledge could contribute to the identification of appropriate topics for agricultural research aimed at smallholder farmers. Where farmers possess agro-ecological knowledge but do not appear to be using it, socio-economic constraints may have over-riding importance in decision making behaviour. Technologies that aggravate these constraints are unlikely to be adopted by farmers, but ones that address them may be relevant.

Using farmers' criteria in the design and evaluation of new technologies may produce outputs more appropriate to their circumstances. During technology development, an explicit focus on farmers' knowledge may be advantageous in improving communication between farmers and researchers and highlighting farmers' criteria for the evaluation of new technologies, particularly when researchers' knowledge and opinions are ordinarily valued and acted on in technology design, rather than those of farmers. For example, criteria used by farmers in making decisions about shade tree retention on farm could inform research on integration of trees and crops and should influence researchers' decisions about which tree species to include in trials both on-station and on-farm. Gaps in farmers' knowledge can also be targeted by research and extension. In Nepal, Shrestha (2003) found that once farmers had learnt about the concept of nutrient leaching which was new to them, they were motivated to experiment with previously unaccepted technologies such as hedgerows and grass strips on terraces. Teaching farmers about integrated pest management has also been successful in motivating them to observe and experiment in different ways in Latin America (Bentley, 1994).

Understanding local knowledge and decision making can also enhance understanding of how and when technologies are appropriate to farmers' agro-ecological and socio-economic circumstances. Low plant survival was one reason farmers gave for burning cleared vegetation during land preparation, suggesting that use of herbicide and mulch during land preparation may only be suitable for some cropping practices, and for some types of fallow vegetation.

The use of AKT5 is one relatively rigorous method for examining local knowledge and trying to understand decision making behaviour. It is a resource intensive method that requires at least two months of full-time intensive work by a single person to create a knowledge base of around two or three hundred statements. Furthermore, it is a method that has a steep learning curve and requires some effort and training to learn. However, rigorous methods which produce lasting results do have advantages. The use of AKT5 results in an explicit account of farmers' knowledge that is fully searchable, and easily and cheaply distributed provided computer access is available. This record of local knowledge can, therefore, be consulted by other people, as accessing a knowledge base is far easier than creating one. It is also a

particularly good method to use for eliciting and storing farmers' knowledge about agro-ecological processes, and for obtaining a detailed understanding of knowledge rather than merely eliciting preferences or value judgements. The AKT5 methodology and other rigorous approaches to recording local knowledge may also have greater utility where farmers' knowledge is particularly rich, as an explicit and lasting record will have more future value than when knowledge is limited. However, without a critical assessment of the level of farmers' knowledge it may difficult to determine in advance whether farmers have just not been asked the right questions in the past, or whether they really lack knowledge.

This research found that farmers appreciated the ability of organic matter to improve the physical structure of the soil and increase moisture availability and its role in providing nutrients to plants. They were aware of its formation through the decomposition of vegetation. They also valued soil cover and used shade to manage weeds through, for example, manipulation of cocoa planting density and mixed cropping practices. This suggests that farmers do not need to be taught that large quantities of organic matter are good for the soil, or of the value of soil cover for reducing weeds. Instead, researchers and extensionists need to work with farmers to find ways of increasing soil organic matter and managing weeds that are effective under farmers' conditions and that use the opportunities and do not aggravate the constraints of farmers' existing asset base. Unfortunately, there is little organic material that is easily and readily available to farmers in labour constrained humid and sub-humid Ghana. Livestock numbers are low outside peri-urban areas and transportation of large quantities of plant biomass to use as green manure is probably not feasible. Whilst greater integration of livestock and crop farming is desirable in the medium to long term, manipulating fallow vegetation may be an appropriate way of improving soil fertility management in the short term.

Leguminous cover crops, and other forms of improved fallow are complex technologies which have a small environmental range over which they are effective (Sumberg *et al.*, 2003). Furthermore, cropping practices, and especially cropping patterns, are diverse in the south of Ghana. It may, therefore, be appropriate to get farmers to take the lead in conducting their own experiments with ways of establishing fallow vegetation, generating large quantities of biomass and/or managing weeds using locally relevant agro-ecological knowledge. Farmers have knowledge about and preferences for different local plants both as weeds and as fallow vegetation. They also have knowledge of variability in land and soil in the area that they farm, and plant species interactions. Experiments where the decision making is done entirely by farmers would exploit this knowledge and could furthermore generate outputs more relevant to local livelihoods.

Farmer led experiments could be facilitated by researchers and/or extensionists. They would provide genetic material and ecological information about fallow species that farmers were unfamiliar with, and advice on other technical issues raised by farmers. They would also organise visits to demonstration sites for farmers to observe the morphology and growth patterns of different fallow species and discuss their attributes with researchers and extensionists. Researchers and extensionists would also record farmers' management practices and decision making.

In farmer designed experiments in Nepal Shrestha (2003) found that incorporating farmers' knowledge in the participatory technology development process was powerful in motivating and empowering them to experiment with new interventions and identify suitable technology options. Partnerships and collaboration between scientists and farmers appeared better able to target research and produce useful outputs than that done by farmers and scientists in isolation. Farmer designed agroforestry experiments in Kenya have revealed the criteria that farmers use in evaluating tree species, and farmers' preferred niches for planting trees on the farm (Franzel *et al.*, 2002b).

The impact of environmental policies and decision making on the livelihoods of smallholder farmers

The local knowledge showed why farmers valued *Chromolaena odorata* on the fallow, and why it was difficult to manage on crop land. The consequences of the suppression of *Chromolaena odorata*, and its implications for soil fertility and the livelihoods of smallholder farmers do not appear to have been considered until recently in Ghana. Other instances where environmental decision making has been based on limited local evidence of environmental processes and limited consideration of the impact of decision making on the land based livelihoods of smallholder farmers can also be found in Ghana. There are by-laws to restrict cultivation within 50 m of water courses to prevent pollution from agro-chemicals and siltation and drying up of water courses (Okali and Sumberg, 1999). These by-laws are not based on actual evidence of the impact of stream-side cultivation on water quality or erosion in particular locations, but on general cause and effect relationships, and the choice of a 50 m exclusion zone is largely arbitrary. If actually implemented, these could make dry season vegetable cultivation unfeasible and could have a significant impact on the livelihoods of many farmers in the Brong Ahafo region (Okali and Sumberg, 1999).

Environmental concerns have also been invoked to manipulate conflicts over the control of natural resources. Amanor *et al.* (2002) has described how young native people in a village in the Brong Ahafo region wrested control over the production of charcoal from Sissala migrants using the local government's environmental concerns, but without any non-partisan local evidence of the destructiveness of charcoal burning. Following this, the chief of this village and of another, who could not obtain revenue from native people who produced charcoal, were attempting to ban production altogether. Elsewhere, in the north of the Brong Ahafo region, clashes between Fulani pastoralists and local farmers, fuelled by rivalry between chiefs for lucrative grazing contracts, resulted in the expulsion of non-Ghanaian Fulani in 1999 to 2000 on the grounds that their cattle were environmentally destructive (Tonah, 2002). Such action may be considered contrary to fostering greater integration between livestock and crop farming in southern Ghana which would be more productive from a soil fertility perspective.

Differences in knowledge distribution

The research found that not all farmers had the same levels of agro-ecological knowledge and that there were different patterns of knowledge distribution for different types of knowledge. For some subjects, knowledge was limited amongst all farmers in a community and would require inputs of knowledge from external sources, via the extension process, to effect change. This included detailed knowledge of animal manure, with which farmers had limited practical experience, and soil pests for which farmers' observational powers were very limited. Knowledge of other subject areas such as inorganic fertiliser existed in most communities, but was unevenly distributed and associated with practical experience. In these cases it may be possible for members of the community to draw on the knowledge of other farmers when they develop an interest in a new farming practice.

Contact with the extension services did not appear to influence farmers' levels of knowledge. This may be because farmers do not retain detailed knowledge about new technologies until they need it. Therefore farmers with more contact with the extension services may not have more detailed knowledge about all technologies. However, there was a positive association between individual contact with the extension services and trial of new technologies. Although farmers who have individual contact with the extension services may not be representative of all resource poor smallholder farmers, this positive association does show that the extension services had some impact on farmers' practices.

5 THE GENERATION AND TRANSMISSION OF KNOWLEDGE: SOIL FERTILITY RESEARCH AND DISSEMINATION IN GHANA

This chapter presents an analysis of soil fertility research and dissemination in Ghana using a case study about cover crop research and dissemination in the Brong Ahafo region. The case study assessed what knowledge existed, and how it was generated and transferred within the research system, from researchers to farmers, and from farmers to researchers in order to identify constraints to knowledge flow and suggest how the process might be improved.

5.1 Cover crop research activity in Ghana

The cover crop mucuna (*Mucuna spp.)* is probably the most researched and most successful single cover crop species so far found for tropical regions. Its successful integration into maize cropping patterns in Latin America has been widely publicised (Anderson *et al.*, 2001; Buckles *et al.*, 1998b). Within West Africa, most mucuna development activity has so far occurred in Benin and has also been hailed as successful (Galiba *et al.*, 1998; Section 2.2.2). Because of the level of knowledge generated from these development activities, mucuna has been considered an obvious choice for improving soil fertility and combating weeds in annual food cropping systems in Ghana.

Within Ghana a number of different research organisations and projects have been experimenting with mucuna and other cover crops for some time. The Crop Research Institute (CRI) and the Soil Research Institute (SRI) in Kumasi have carried out on-station and on-farm trials for over ten years (Osei-Bonsu and Asibuo, 1995). The University of Ghana, Legon has conducted long term trials integrating cover crops with livestock and tree crops and the Savanna Agricultural Research Institute (SARI) has carried out cover crop research in the northern savanna zones (Dogbe, 1998; Fianu, 1998; Frey *et al.*, in press). However farmers' use of cover crops has so far been limited and restricted to use of *Pueraria phaseoloides* under large scale oil palm plantations for weed management (Section 4.2.2).

The Brong Ahafo region was the main focus of cover crop research and extension activity in the forest and transition zones of Ghana during the period 2000 to 2001. The most intensive legume research efforts had been carried out relatively recently by two projects originating outside of the national agricultural research and extension system, but working very closely

with it. The Integrated Food Crops System Project (IFCSP) was a research project funded by the Department for International Development (DFID) and conducted by the Natural Resources Institute, UK and the Ministry of Food and Agriculture, Ghana (MOFA). The soil fertility research component of the project ran from 1997 to 2000 and included on-station and on-farm trials of different legume species as green manures for commercial tomato production. Outputs of the project included extension guidelines for cultivating and incorporating mucuna and *Canavalia ensiformis* (canavalia) to increase soil nutrients, improve soil water holding capacity and increase tomato yield and the quality of fruit (NRI, 2000).

Cover crop activity has focused on the Sedentary Farming Systems Project (SFSP), funded by GTZ (the German Development Co-operation). This project was initiated in 1996 to develop sustainable sedentary farming systems in the Brong Ahafo region and soil fertility was only one element of its overall program. All its activities were carried out through MOFA whose extension agents acted as the direct links between the project and farmers (Anthofer, 2000). As a development project, its focus was on extending interventions to improve rural livelihoods, but it became involved in adaptive research where it was necessary and employed a PhD student to carry out trials with mucuna. The SFSP's cover crop research and development activities produced at least two different ways of integrating mucuna into cropping patterns and one way of integrating canavalia in three pilot districts with broadly different agro-ecology, spanning forest, transition and savanna zones (Loos *et al.*, in press; Osei-Adade *et al.*, in press). By 2000, the project had recorded over 240 farmers working with cover crops in the three districts and cover crops were starting to spread more from farmer to farmer with less input from extension agents and community motivators (SFSP, unpublished data).

The case study of cover crops in the Brong Ahafo region was used to identify the constraints to the transfer of knowledge of soil fertility management between farmers and researchers. The case study assessed:

- how knowledge is stored within the research system internationally, and in Ghana,
- how knowledge is transferred between different actors and organisations within the research and extension system in Ghana,
- how the outputs of research are extended to farmers and
- how knowledge is transferred from farmers to researchers in the development of technologies and the provision of feedback to researchers.

5.2 Methodology

The research was carried out from January to March 2001 and consisted of three main activities. A database of sources of information about cover crops with particular emphasis on West Africa was created using Microsoft Access. It included databases, mailing lists, websites, reviews and conference proceedings. This was used to access what documented cover crop information was available to researchers in Ghana and how it was stored.

Semi-structured interviews were carried out with researchers and extensionists who had worked with cover crops to understand the research that had been carried out and how it had been extended to farmers, and to gauge researchers' perceptions on the accessibility of information and knowledge transfer. Those interviewed included four members of the National Agricultural Research System who had worked with cover crops as well as researchers and development workers involved in the SFSP. Project documents and other relevant literature were also consulted.

A cover crop knowledge base (cover crops.kb) was created using the Agroecological Knowledge Toolkit 5 (AKT5) software (Section 4.1.1) to assess knowledge flow and to document knowledge storage. Internationally held knowledge of cover crops and knowledge held by members of the National Agricultural Research System and the National Agricultural Extension System was entered. This was done in Ghana, where the majority of cover crop research had involved mucuna and, therefore, the majority of the statements in the knowledge base were about mucuna. This knowledge was taken from reviews and research articles, conference proceedings, extension leaflets and interviews with national researchers and extension workers.

5.3 Cover crop knowledge within research and extension

The cover crops knowledge base contained 753 statements, three quarters of which were about the cover crop mucuna. Statements about mucuna covered a wide range of topics from optimum soil characteristics for cultivation to the most desirable time for planting and weeding (Table 5.1).

Table 5.1 Number of statements about different aspects of mucuna in the cover crops knowledge base

Topic	Number of statements
Application of fertiliser to mucuna	6
Biomass production	85
Crop interaction with mucuna	50
Drought tolerance	10
Effect of mucuna on the yield of a subsequent crop	18
Establishment	36
Ground cover	44
Human food uses	20
Intercropping mucuna	10
Livestock feed use	14
Management of mucuna residue	20
Mucuna requirements for cover cropping	12
Mucuna varietal information	298
Nematodes	8
Nitrogen fixation	10
PH	6
Persistence of mucuna biomass through the dry season	13
Pests and diseases	7
Phosphorus	7
Seed production	11
Soil properties	47
Sole cropping of mucuna	14
Weed suppression	21
Weeding requirements	20
Total mucuna statements	575

Mucuna exhibits a lot of genetic diversity and more than half of the statements were about characteristics of different genotypes. Lack of common nomenclature was confusing and 35 different names for mucuna genotypes were recorded in the knowledge base. International research publications usually referred to a seed source, but not all national publications did this. Extension workers referred to seed colour and crop duration. Genotype information referred mostly to the physical characteristics of flowers and seeds, days to flowering and maturation, percentage ground cover, biomass production and senescence during the dry season. Flower and seed characteristics were important for distinguishing between different genotypes. Biomass production, life cycle duration, and the rate of development and senescence of ground cover were important in evaluating the potential of different genotypes for weed suppression and nutrient cycling.

There were only 21 statements in the knowledge base explicitly about intercropping cover crops with other crops, ten of which were from Ghana. Establishing cover crops alongside food crops can reduce the labour demands for establishing the cover crop. Characteristics of individual cover crops and genotypes such as growth habit and rate of development can also be used to estimate ecological compatibility with other crops. However the low number of statements explicitly about intercropping reflected the little research that has been carried out

so far and the limited number of cropping patterns that have been targeted for research in Ghana.

The benefits and costs of growing a cover crop were highly variable. An extension agent estimated that the majority of farmers weeded twice when mucuna was being sole cropped, whereas extension literature and researchers estimated that one weeding would be sufficient. Increases in the yield of maize after mucuna also varied depending on the initial fertility of the soil. More fertile soils benefited less from cover cropping, whereas yield increases were higher when cover crops were used on soils low in fertility. Crop management was also important. Estimates of yield increases in Ghana were as much as 100% under researcher management, whereas the SFSP estimated 30 – 70 % under farmer management.

There were some broad differences between the knowledge held by research and extension. There was more information on the characteristics and performance of different mucuna accessions in the research system than in the extension system. Research also held more quantitative knowledge about biomass production and ground cover than extension, primarily as a result of trials of different genotypes. There was more knowledge within the extension system about intercropping mucuna with food crops. Extension agents interviewed associated with the SFSP were very articulate about the mucuna technology. The SFSP's Participatory Technology Development was carried out by working very closely with extension agents, and the extension agents had also received training to improve their analytical skills and the quality of their interaction with farmers.

5.4 The role of research and extension in the generation and transmission of knowledge

Figure 5.1 provides an overview of how knowledge about cover crops is generated and transferred between researchers, extensionists and farmers in Ghana.

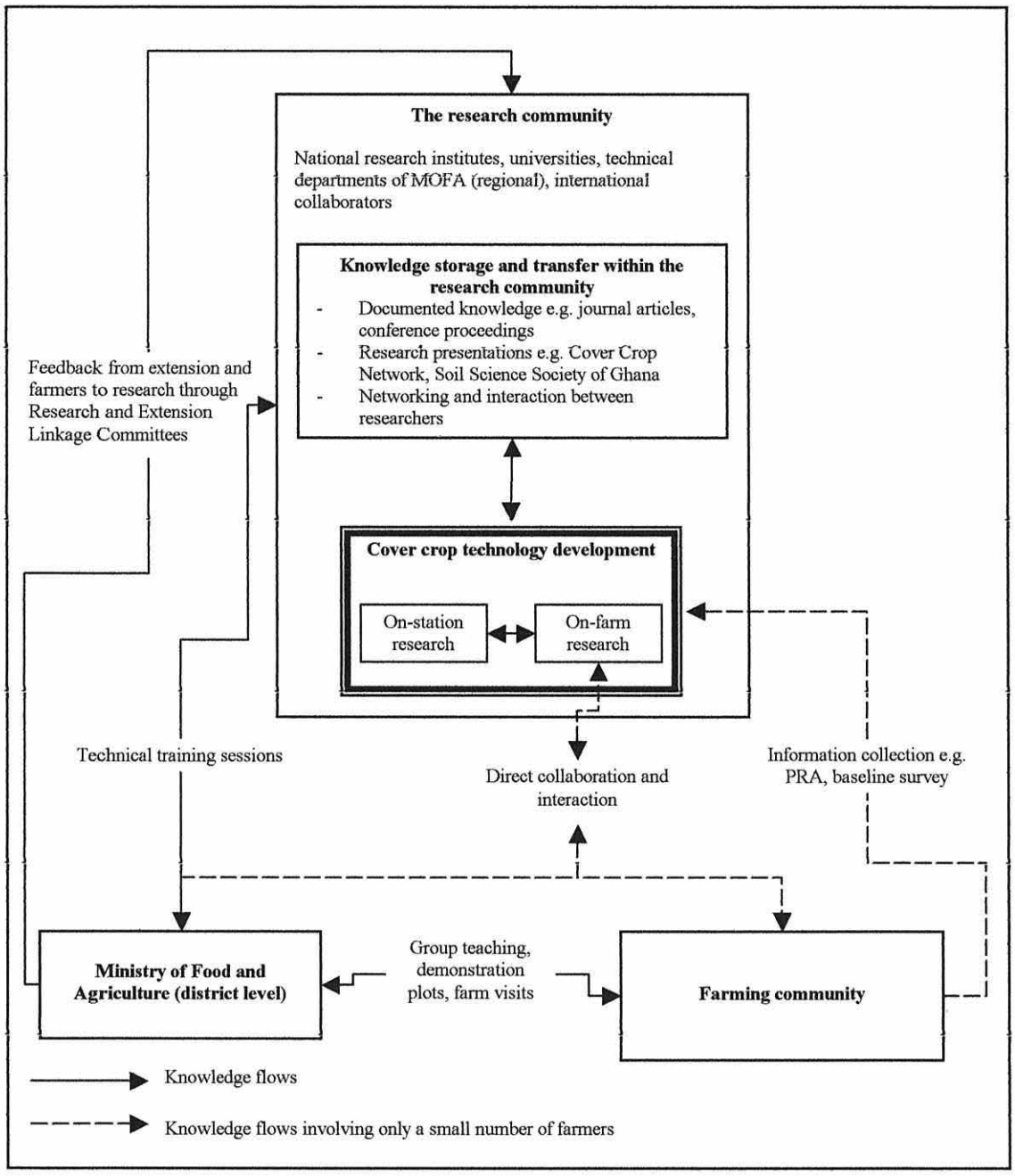


Figure 5.1 Knowledge transfer during the development and dissemination of cover crop technologies in Ghana

During technology development, researchers' drew on knowledge that was held within the wider research community documented in books and journals, and communicated through research presentations, conferences and interaction with other researchers. Sources of knowledge and knowledge flow within the research system are assessed in Section 5.4.1. Information was also obtained directly from the farming population through baseline surveys and PRA activities. More generally, feedback from farmers was channelled through the extension system through forums such as Research and Extension Linkage Committees (RELC) which are intended to contribute towards setting the research agenda. Technology

development could involve both on-station and on-farm trials. On-farm trials were frequently implemented through the district extension services and hence involved direct collaboration and interaction amongst researchers, extensionists and farmers. Section 5.4.2 assesses knowledge flows from farmers to research during cover crop technology development. The results of research outputs were communicated to farmers through the extension system which uses the World Bank's training and visit model. Technical specialists train extension agents in the use of particular technologies. Extension agents then implement demonstration trials and carry out group training and farm visits. Feedback from farmers is obtained through these interactions. Dissemination of cover crop technologies is assessed in Section 5.4.3.

5.4.1 Knowledge flow within the research system

Building on the outputs of previous research is important to avoid repetition and to make research more efficient and effective. How researchers become aware of new knowledge or research outputs, the way in which knowledge is stored, and the medium through which documented knowledge is obtained all influence the accessibility of knowledge.

5.4.1.1 Sources of knowledge

Within the research system knowledge was communicated to other researchers through documentation, presentations, networking and interaction with other researchers. Table 5.2 shows the main sources of knowledge about cover crops most relevant to researchers in West Africa at the time of the research. Outputs of cover crop research were documented in databases, books, journals, monographs, reports and conference proceedings. Exchange of information about more recent research occurred through conferences, websites, newsletters and electronic discussion groups. Researchers also communicated directly with one another both locally and internationally.

Table 5.2 Sources of cover crop information and their accessibility to researchers in Ghana in March 2001

Information source	Most relevant sources for researchers in West Africa	Type of information	Requirements for use
Databases	*Cover crops: a review and database for field users* (Kiff *et al.*, 1996) LEXSYS (Legume Expert System) (Weber *et al.*, 1997) Organic Resources Database (Gachengo *et al.*, 1998)	Cover crops and LEXSYS synthesise large amounts of information to enable users to make initial selection of promising species for field trials. The Organic Resource Database synthesises large amounts of information on plant nutrient and feed quality of various species and organic substances.	Free distribution but computer access, computer skills and appropriate software necessary for use
Books, monographs and conference proceedings	*Mucuna: herbaceous cover legume with potential for multiple uses. Resource and Crop Management Research Monograph No. 25* (Carsky *et al.*, 1998) Proceedings include Buckles *et al.* (1998a) and Carsky *et al.* (2000)	The International Institute of Tropical Agriculture's Mucuna monograph documents the state of knowledge on mucuna as of 1998 and is aimed at researchers in Africa. Conference proceedings provide information on recent research.	Free distribution of many publications to researchers in developing countries.
Journals, theses etc.	International journals. National journals such as the Ghanaian Journal of Science, the Journal of the Ghana Science Association and the Soil Science Society of Ghana.	Recent research	Access to recent journals
Reports	Unpublished project reports e.g. Jackson *et al.* (1999) Annual reports from research institutes such as CRI	Unpublished documentation of research activities	Must be requested from source
Websites	Management of Organic Inputs in Soils of the Tropics (MOIST) Cover Crops for Sustainable Agriculture CCropNet Web Site	Information on recent and ongoing research and development activities with references to other sources of potentially useful information.	Internet access
National and international conferences and network meetings	Soil Science Society of Ghana Ghana Cover Crop Network	Information on recent regional developments in cover crop research and development	Conference invitations and funds to attend.
Newsletters	The Cover Crop Information and Seed Exchange Centre for Africa's (CIEPCA) newsletter *Mucuna News: developing multiple uses for a proven green manure/cover crop*	Information on recent regional developments in cover crops research and development with references to other sources of potentially useful information	Free distribution
Electronic discussion groups	MULCH-L EVECS-L	On-line discussion for exchange of information on green manures, cover crops and soil fertility	Email access

Access to knowledge of cover crop research that has been done in Ghana itself is important to prevent research work being duplicated and because of its relevance to local agro-ecological and socio-economic conditions. Research reports were often produced for the donors of externally funded research, but their production and distribution was associated with international research partners. There was a lack of documentation of cover crop research activities by national research organisations and hence of research activities without international research partners. Research institutes did not produce annual reports every year and internal reporting was minimal. The author did not find and was not referred to any internal reports or unpublished documents with relevant information on cover crops. Furthermore, the publication of Ghanaian journals and conference proceedings was often delayed and several years of contributions might be published in one issue. Hence much research work remained within the heads and offices of individual researchers. Conferences and network meetings were important forums for sharing research experiences as there were no formal links between research institutes. However, in the absence of publication outlets, researchers were wary of sharing unpublished material in the fear that others might publish it first without acknowledging them and one such instance was encountered during the course of the case study.

Interviews with cover crop researchers in national research institutes in Ghana found that freely distributed newsletters, conference attendance and conference proceedings were important mediums for the exchange of knowledge amongst national and international researchers. CIEPCA's (Cover Crop Information and Seed Exchange Centre for Africa) newsletter was widely received by researchers in Ghana. Conferences and network meetings such as the Ghana Cover Crop Network were important means for establishing contact with international researchers and for networking nationally, especially in the absence of documentation of national research activities or formal links between research institutes. However, there was little use of cover crop databases, websites or electronic discussion groups.

5.4.1.2 The role of information technology and the accessibility of documented knowledge

Important mediums for generating awareness of new cover crop knowledge resources were database searches for journal articles and books, websites, electronic discussion groups, newsletters and networking with other researchers. Access to internationally documented knowledge and recent international research was vastly facilitated by access to computers, email and the internet. These facilities were also important for linking researchers with international cover crop research, and particularly with the most recent research (Table 5.3).

Table 5.3 Information technology requirements for mediums through which awareness of new cover crop research is generated

Medium	Information technology requirements			
	None	Computer	Email	Internet
Newsletters	√			
Local networking (within Ghana at conferences and network meetings)	√			
Distance networking (with researchers abroad)		√	√	
Database literature searches		√		
Websites		√		√
Electronic discussion groups		√	√	

In Ghana, access to computers, email and the internet varied between research organisations. In Kumasi the development and use of internet cafés was just occurring at the time of the research. Database literature searches were possible where research institutes could provide access to computers with some institutes providing email and internet facilities, although this did not appear to be the norm. Researchers, therefore, needed a pro-active approach to acquire computer skills, access to computers and use of the internet.

Newsletters, local networks and conferences were important in Ghana and did not have information technology requirements. Once researchers were aware of documented outputs from international research some forms were relatively easy to obtain free of charge including newsletters, monographs, cover crop databases and conference proceedings. Many publications produced by international research centres were free of charge to researchers in developing countries and CTA (Technical Centre for Agricultural and Rural Cooperation) had a sponsorship scheme through which researchers could obtain books at no charge.

Libraries and inter-library loans, the internet, and personal contact with other researchers were other ways of obtaining documented knowledge. There were libraries attached to research institutes, universities and other resources centres such as NGOs. The services provided varied and were largely dependent on recent external financial support. Where resources were limited, GAINS (Ghana Agricultural Information Service) Question and Answer Service could be used to do a literature search and provide interlibrary loans. However it remained difficult for researchers to access the most recently published journal editions (within the last two or three years), necessary for them to write articles for publication in international journals.

5.4.1.3 Summary

Overall, access to information about cover crops from a variety of national and international sources was possible for researchers in Ghana. However, documented knowledge tended to be

scattered, and access to computers, email and internet was possible but not necessarily convenient or reliable. This situation, is however, likely to improve in the future and email, internet and library services were visibly improving during the time of the research, both in the private sector in Kumasi, and within some research institutes. There was a high level of dependence on external funding for maintaining information resources, indicating a lack of capacity in government agencies and research institutes in this aspect of research support. There was also limited documentation of research activities within the national research system, and no formal linkages between research institutes. Individual researchers required a pro-active, motivated approach to keep abreast of developments in national and international research and formal and informal networking were a very important means of doing this.

5.4.2 Farmer involvement in the generation of knowledge through on-farm research

Agricultural research and dissemination in Ghana is carried out by a diverse range of national and international actors. The most important component of the national research system is the Council for Scientific and Industrial Research (CSIR) which is a semi-autonomous organisation under the auspices of the Ministry of Environment, Science and Technology and is responsible for co-ordinating most research in Ghana (Amanor *et al.*, 1993). There are nine research institutes[21] under CSIR which undertake research relevant to agriculture. The universities are the second most important research components after CSIR, and despite shortages of funding have built up a range of research facilities including experimental farms and research stations (Amanor *et al.*, 1993). Parastatal and private enterprises often carry out research in close collaboration with CSIR. The Cotton Company in Tamale and oil palm estates with outgrowers' networks provide services to smallholder farmers (Amanor *et al.*, 1993; MOFA, 1998). Cocoa research is conducted by the Cocoa Research Institute of Ghana (CRIG), which is managed by the parastatal Ghana Cocoa Board and has received a disproportionately large share of agricultural research funding (Amanor *et al.*, 1993). Technical specialists from the regional directorates of the Ministry of Food and Agriculture are also active in research. International organisations such as members of CGIAR, universities and international NGOs collaborate with the national research institutes under the

[21] Institutes under CSIR directly or indirectly involved in agricultural research are the Animal Research Institute (Accra), Crop Research Institute (Kumasi), Food Research Institute (Accra), Forestry Research Institute of Ghana (Kumasi), Oil Palm Research Institute (Kade), Plant Genetic Resources Centre (Bunso), Savanna Agricultural Research Institute (Nyankpala), Soil Research Institute (Kumasi) and the Water Research Institute, Accra.

Council for Scientific and Industrial Research (CSIR), the universities, the Ministry of Food and Agriculture (MOFA) and national NGOs.

5.4.2.1 Technology development within the national agricultural research system

Prior to the IFCSP and the IFSP, on-station cover crop research had focused on the potential of cover crops for improving soil fertility or combating weeds, giving secondary consideration to fitting legumes into existing farming systems until the functional basis of the technology had been adequately proven. Much of this research had taken place on-station.

On-farm trials were considered to be the final stage in technology development at the Crop Research Institute and cover crops trials had mainly been conducted in the Ashanti region with some trials in the Brong Ahafo region in 1993 as part of the Ghana Grains Development Project, which was supported by the Canadian International Development Agency. During these on-farm trials the researcher gave the technology package, comprising cover crop seed and information, to an extension agent. The extension agent implemented the trials with contact farmers, from which the researcher could collect data. Fewer trials had been conducted by the Crop Research Institute since the end of the Ghana Grains Development Project and these were usually part of externally funded projects. Overall, on-farm trials were far fewer than on-station trials, and those trials that did take place did not involve farmer participation in technology design.

Following recognition of the problems facing the research and extension system in providing sufficient feedback from farmers to research, Research and Extension Linkage Committees (RELC) were put in place in 1993 in each of the five main agro-ecological zones of the country in an attempt to achieve greater communication between farmers, extension staff and researchers (Dulcire *et al.*, 1999). Although they were intended to be important instruments in setting the research agenda and obtaining feedback from farmers on adaptive trials, at the time of the present research, these committees had not been meeting regularly. Both research and extension activities were heavily reliant on external funding and at the time of the research, extension was in a hiatus between the end of the National Agriculture Extension Project and the beginning of the Agricultural Services Sub-Sector Investment Programme. Furthermore, the inclusion of RELCs in planning research and extension was a relatively recent innovation. Although they have improved the accountability of agricultural research to end users, they have not yet been successful in taking account of the realities of smallholder farmers (Dulcire *et al.*, 1999).

5.4.2.2 Technology development under the IFCSP and SFSP

Both the IFCSP and the SFSP conducted on-station and on-farm trials which built on knowledge of previous research of cover crops, both internationally, and in Ghana. The IFCSP tested a range of legumes to find those best suited to integrating as green manures in commercial tomato cropping patterns, producing soil fertility technologies ready for dissemination in just three years. The SFSP offered a range of soil fertility technologies to farmers of which cover cropping was the most popular and promising. Later, it adopted a participatory technology development approach and employed a German PhD student to carry out trials with mucuna, working closely with extension agents and farmers (Anthofer, 2000).

Despite having a development, rather than a research remit, the SFSP made a lot of progress in finding ways of integrating legumes into the food cropping patterns of the three agro-ecological zones in which it was working. In the transition area, the project produced two different ways of integrating *Mucuna pruriens* into maize cropping patterns. The first involved relay cropping a long duration variety of mucuna into maize during the major season and leaving it to develop during the minor season. The second involved planting a shorter duration variety of mucuna after the maize harvest in the minor season. This alternative was suitable where maize had been planted late, but its establishment costs were higher than for relay cropping mucuna with maize, as weeding of the mucuna was required. The project found that maize yields increased by 50 to 100% the following year and that any crop could be planted through the mucuna mulch (Loos *et al.*, in press).

In the savanna area further north the rainy season was shorter. Mucuna, therefore, had to be grown for a whole cropping season. Farmers found its main benefit was in reducing the infestation of *Imperata cylindrica*, rather than in increasing maize yields (Loos *et al.*, in press). In the forest area to the south, rainfall was higher than in either the transition or savanna areas, and farmers' food production systems focused on plantain based intercropping. Mucuna's aggressive climbing growth habit was unsuitable. Instead the project found a way of intercropping *Canavalia ensiformis* three months after planting plantain suckers, which contributed to more economical weed control (Osei-Adade *et al.*, in press).

Despite the SFSP's success, the diversity in cropping patterns and the socio-economic circumstances of farmers in the Brong Ahafo region may result in the mucuna technologies produced only being appropriate to a narrow range of farmers. Establishing a legume as an intercrop reduces weeding requirements, making it more compatible with labour scarce smallholder agriculture but mucuna is only suitable for intercropping with tall statured crops,

soon before final harvesting because of its aggressive, climbing growth habit. It is, therefore, only suitable for a limited number of cropping patterns and can only be relay cropped with maize by forfeiting intercrops. Although maize is an important cash crop, it is at least as common to intercrop maize, particularly with cassava, as it is to grow it as a sole crop (Section 3.4.3.2; Amanor *et al.*, 2002). Furthermore, tenant farmers, who were frequently allocated the least fertile land at the Brong Ahafo field sites studied during this research, often had the lowest tenure security and only had access to land for one or two years (Section 3.4.3.3). Therefore, although maize is a very common cash crop, integrating it with mucuna is only attractive and possible under limited and specific circumstances and may only be appropriate to a small proportion of farmers with little access to fertile land but high security of tenure.

There still remains a lot of potential for developing additional ways of integrating legumes with food crops. Consultation of various cover crop databases (Table 5.2) showed that there were a large number of potential cover crops available for tropical environments. Knowledge about different species varied depending on the research effort that had already been carried out. Although the IFCSP tested a range of species, the SFSP with its development remit concentrated on legumes which had already proven successful in Ghana and internationally. Further experimentation could be carried out to identify other promising legume species compatible with cropping patterns and farming systems in the Brong Ahafo region. There is also a lot of genetic diversity within mucuna (Section 5.3) which could also be tested and further exploited within the cropping patterns and agro-ecological conditions of Ghana (Carsky *et al.*, 1998).

The SFSP's participatory development activities produced lessons about how to interact with farmers effectively in identifying areas for potential collaboration (GTZ/MOFA, 2000b). They found that farmers had pre-existing perceptions toward research and development activities that needed to be recognised before effective collaboration between farmers, researchers, extensionists and development workers could take place. Farmers' perceptions about the role of the project and its activities were shaped by the way in which extension agents held group meetings and presented technologies to farmers. Farmers easily held incorrect expectations about what a project would provide, and presented their problems accordingly, and extension agents were trained to reshape expectations within the community in a respectful manner using appropriate language.

5.4.2.3 Summary

Much progress has been made by the SFSP and IFCSP towards integrating legumes into food cropping patterns building on previous cover crops research internationally and in Ghana. The SFSP with its development remit initially built on the outputs from previous successful research on integrating legumes into food cropping patterns. Later on, it responded to the diversity in rainfall and cropping patterns in the Brong Ahafo region by developing ways of integrating legumes into areas with different cropping patterns and rainfall. However the legume systems developed have specific resource requirements that may limit wider uptake. Obtaining feedback on the socio-economic characteristics of farmer adopters, their cropping patterns and the performance of the legume technologies under farmer management could provide valuable information about the scope of the technologies. There is still a lot of potential for exploiting other legumes and other varieties of mucuna in finding ways to integrate them with crops other than maize and plantain.

Overall, few on-farm trials were carried out by national research institutes in the absence of externally funded projects, and those on-farm trials that were carried out had low levels of farmer participation in technology design. Furthermore, feedback from farmers and extension to research was limited under the national agricultural extension system as the communication channels put in place were not functioning.

5.4.3 Technology dissemination

The main means through which agricultural technologies are disseminated in Ghana is through the Unified Extension System which is operated by the Department of Agricultural Extension Services (DAES) of MOFA using the Training and Visit extension model which covers the whole of the country. Extension activities are organised at the district level and all extension messages are channelled through a single Agricultural Extension Agent (AEA) (Figure 5.2). Extension agents attend monthly training sessions given by resource persons drawn from MOFA's technical departments, or else from research, and then visit groups of around ten contact farmers every fortnight. They hold group meetings, demonstrate technologies and interact with individual farmers. Bimonthly technical review meetings and Research and Extension Linkage Committees (RELC) are intended to ensure effective linkages between research, extension and farmers.

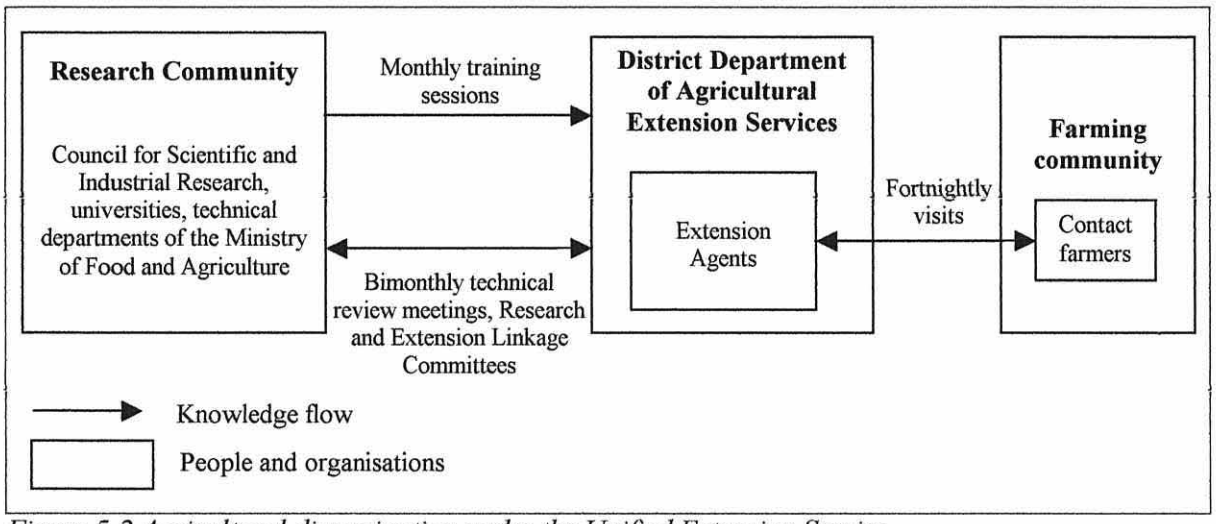


Figure 5.2 Agricultural dissemination under the Unified Extension Service

In addition to MOFA, national and international NGOs are involved in agricultural extension. Some of these organisations streamline their activities through MOFA. Others, whilst maintaining some degree of collaboration with MOFA, use alternative extension approaches such as Farmer Field Schools to interact directly with farmers. However the geographical coverage of these programmes is very small. Research also links directly with farmers through farmer, extension and researcher collaboration in on-farm research (Section 5.4.2), but the geographical area and number of farmers involved are small. Parastatal and private enterprises carry out research and extension activities for cotton and oil palm in some areas.

5.4.3.1 Extension of cover crop technologies in the Brong Ahafo region

Extension workers in the Brong Ahafo region had not received cover crop training outside of externally funded projects and there had been no co-ordinated attempt on the part of MOFA to promote cover crops. Promotion of cover crops had therefore only taken place with the funding and at the initiative of externally funded location specific and short-term projects.

One potential reason for this was the lack of available funding for field activities such as transport and training of extension agents. Resource persons brought in from other organisations to train extension agents required payment. Each extension agent was expected to make 16 visits each month to relatively remote locations. Motorbikes, together with allowances for fuel and maintenance were considered necessary. Low salaries, slow promotions, lack of funding for field activities and other problems all resulted in low morale amongst some MOFA staff. Therefore, not all staff were well motivated, and even the most dedicated could not finance their work from their own pockets and had to invest time in other income generating activities.

Both the IFCSP and the SFSP had made some effort towards extending the technologies they had tested to the larger farming community in the Brong Ahafo region through MOFA. Within their three year remit the IFCSP produced a manual (Awiti *et al.*, 2000) and a number of extension leaflets for vegetable production. A further phase of the project was being implemented to produce extension material appropriate to the training needs of the extension service.

The SFSP as a development project with a longer term remit and the opportunity to conduct extended capacity building in the extension services was more successful in passing the results of research to farmers more quickly. They identified and responded to problems within the current extension system.

The SFSP put considerable effort into capacity building with extension agents in an attempt to obtain a better two way interaction with farmers. They found that extension agents preferred to deliver packaged technologies as this minimised the requirements to think through the implications of the recommendations that they were making. The SFSP also identified the need to undertake technology training with extension agents in an environment closer to the one in which the extension agent would be working, that is, at the village level. They also found that extension agents would benefit from techniques applied in adult education (GTZ/MOFA, 2000a; GTZ/MOFA, 2000b). The SFSP did not just provide training in new technologies to extension workers, but also trained them in PRA, problem identification and solution finding, and in community organisation and mobilisation. They choose staff carefully and only worked with the better motivated and hard working extension agents.

The SFSP realised that the extension agents were overburdened by the Unified Extension System. They were expected to be conversant with all agricultural topics and this was unrealistic. It was suggested that it would be more feasible for extension agents to play the role of facilitator between the farmer and the source of information (GTZ/MOFA, 2000a; GTZ/MOFA, 2000b). However this would involve a considerable modification in the type and form of information currently available at district level. A different form of interaction between extension agents and farmers would also be required.

Extension agents promoting mucuna felt that provision of seeds to farmers was an integral part of the technology package. Farmers relied on extension agents to provide seed and were unlikely to try cultivating mucuna where seeds could not easily be obtained. Extension agents were, therefore, reluctant to promote the technology to farmers when they did not have a

source of seeds, as they readily become burdened with supplying them. Seed supply is likely to remain an issue until a cover crop is in sufficiently widespread use for the passage of seeds from farmer to farmer. Districts promoting cover crops independently of the SFSP would need to consider how to source seed. Such an activity might be better suited to regional co-ordination. However, this has financial and organisational implications requiring commitment from the appropriate MOFA directorate.

The SFSP had been working in three pilot districts in the Brong Ahafo region but interest in and knowledge of technologies produced by the project had been limited in other districts. This was symptomatic of organisational problems and a lack of horizontal linkages within the extension system. Both district and regional MOFA directorates received their budgets directly from Accra and regional co-ordination of extension activities was limited. Furthermore, district staff were not pro-active in information gathering about new and interesting technologies, but mostly waited for directives from above or invitations from projects. Lack of funding for information gathering and implementation of training contributed to this problem, although the bureaucratic nature of the extension services probably also stifled initiative and resourcefulness. The Cover Crop Network enhanced horizontal linkages between researchers and MOFA's technical staff at regional level, but was too specialised for district directors of agriculture.

5.4.3.2 Summary

Technology dissemination could be achieved more rapidly if district extension services adopted a more pro-active approach to information gathering and if there were better horizontal linkages between districts, projects and NGOs to enhance information sharing. The extension services have only been partially decentralised, but once fiscal decentralisation has taken place budgets will be received from the district assemblies and district extension services will become autonomous from central directives. Where the extension services are promoting cover crops or other technologies requiring inputs such as seed, consideration also needs to be given to how input supply can be coordinated with extension delivery. There may be a role for regional extension directorates in ensuring that effective networking takes place, and in the provision of seed to the districts. The extension services faced limitations in the resources available for field extension activities and the training of extension staff. Furthermore, the amount of information extension agents were expected to be familiar with was unrealistic, and they preferred to present packaged technologies to farmers rather than analysing farmers' circumstances. Alternative extension models where extension agents facilitate farmers' access to information would require capacity building amongst extension

staff to improve their ability to analyse farming systems, and greater information resources available at district level.

5.5 Conclusions

This case study highlighted constraints in agricultural technology development and dissemination in Ghana which were similar to the problems faced by other African countries. The limited success of national and international research and extension in reaching smallholder farmers in sub-Saharan Africa has been attributed to both the limited resources available, particularly within national research and extension systems, and with the way in which research and extension is carried out.

Research and extension is frequently carried out in a challenging context which imposes many obstacles for efficient and effective work. National budgets have limited resources available for investment in research and extension and so rely on foreign donors (Pretty and Chambers, 1991). Furthermore, hierarchical bureaucratic systems, a multiplicity of agencies and departments and unofficial practices (or corruption) all impose obstacles for quick and effective action (Moris, 1991). Some of the implications of this context include:

- research managers who mould their efforts to meet donor interests rather than implementing prioritised research objectives and increasing institutional capacity for client-orientated research (World Bank, 1985),
- public sector extension systems devised and set up by external agencies such as the World Bank and USAID which have high recurrent costs which are unsustainable without donor funding (Bagchee, 1994; Garforth and Harford, 1997),
- low levels of funding available, once salaries have been paid, for actual research activities, particularly on-farm, and for training, monitoring and evaluation and actual extension within national extension systems (World Bank, 1985; Bagchee, 1994),
- high staff turnover and loss of the most qualified and experienced staff in public sector research institutes and low staff morale amongst some public sector extension workers (Lipton, 1988; Davies, 1989; Moris, 1991).

These issues were apparent in Ghana. However, although the case study did highlight constraints within the current system of technology dissemination, what was most apparent with regard to cover crops, and other soil fertility technologies, was the lack of research outputs appropriate to farmers' circumstances and ready for dissemination. Past research had concentrated on solutions involving imported agro-chemical inputs which were often unsuitable for smallholder farmers following the loss of subsidies and macro-economic

changes following structural adjustment (Section 2.3). It had also given less consideration to increasing the profitability of labour, rather than that of land. The inability of the research system, and particularly of the CSIR research institutes, to respond to the needs of smallholder farmers has been noted in other assessments including Arokoyo (1998), Dulcire *et al.* (1999) and Albert *et al.* (2000). Arokoyo (1998), who assessed the development and dissemination of a number of agricultural technologies in Nigeria and Ghana, concluded that low adoption of technologies was not primarily due to lack of dissemination amongst farmers, although the quantity and quality of extension coverage was limited, but that end-user participation in every phase of technology development was necessary to produce outputs appropriate to farmers' circumstances.

The effectiveness of research and extension in developing agricultural technologies that are adopted by farmers is linked to the research approach that is used and the type of agricultural technology that is being developed. Collinson (2001) has attributed the slowness of small farmers to adopt new technologies to the dominance of the applied research paradigm in agricultural research. This paradigm seeks the technically ideal management system for a given commodity in a given environment, whilst failing to recognise the goals and evaluation criteria used by smallholder farmers.

Most agricultural research institutes, at both national level, including those of Ghana, and within the CGIAR are organised along the lines of commodities and disciplines with organisations or departments specialising in a particular crop or discipline. This commodity or disciplinary based research approach, together with the historically top-down organisation of research and extension, has biased research towards technically ideal solutions and recommendations with insufficient consideration of their relevance to specific situations (Collinson, 2001). Those developing and extending new agricultural practices have not been accountable to smallholder farmers and the outputs of research have thus been more supply, than demand driven, and have failed to take into account important aspects of the biophysical and socio-economic context of smallholder agriculture. Three key failings have been lack of recognition that improved labour and capital productivity are farmers' primary goals, rather than improved physical productivity of the land; failure to recognise the implications of economic and cultural diversity in technology design, and failure to develop technologies with sufficient flexibility to be suited to farming systems where farmers lack control over the environment and their own resources (Collinson, 2001; Reece and Sumberg, 2003).

Both Douthwaite *et al.* (2001) and Sumberg *et al.* (2003) have suggested that different approaches to technology development and transfer are suited to different smallholder

environmental conditions and different types of technology. The top down approach to technology transfer is likely to have most success with simple technologies, such as new crop varieties, that are easy to understand and use and require little adaptation to fit into existing farming systems. Complex technologies which require coordination of a number of different components or a high level of change to existing farming practices, such as the use of cover crops, may require greater user involvement in technology design to produce results that are relevant to farmer circumstances. Similarly, where farming systems are complex, such as in less favourable production environments where there is variability in agro-climatic conditions, early farmer involvement in the research process may also be necessary to produce relevant outputs. Hence, the separation of research and extension is not appropriate with complex technologies as adaptation by end users and other key stakeholders can result in rapid and important changes to the technology which have significant effects on its effectiveness and hence adoptability. Furthermore, initial adoption and adaptation can benefit from the experience of the original research team (Douthwaite *et al.*, 2001).

However, the stage at which participation in technology development by end users or other key stakeholders is effective depends on the novelty of the technology, that is, the extent to which it is an improvement of an existing technique or a wholly new concept (Douthwaite *et al.*, 2001). For the latter, a working prototype will be necessary to demonstrate the potential of the technology, stimulate interest in development and reduce the risks of adoption. Ultimately, this means that whilst development and dissemination of high yielding cereals has been one of the most successful agricultural innovations in achieving widespread adoption despite low user participation, development and dissemination of novel, complex technologies in less productive agricultural areas remains the greatest challenge, necessitating both a working prototype followed by a high level of farmer participation in further technology development.

This reasoning suggests that for cover crops, a complex technology, in the Brong Ahafo region and Ghana more generally, where there is complexity in livelihoods and farming systems, farmer participation in the research process is essential to produce appropriate technologies. Cover crop research in Ghana has now produced prototype technologies for integrating legumes into cropping patterns. Further participatory research into improved fallows could build on the success of these prototypes, and by targeting farmers and areas experiencing the greatest land shortage, would be most likely to have success in finding additional ways of integrating legumes into cropping patterns which are compatible with farmers' circumstances.

Nevertheless, achieving effective end user participation in technology development, remains difficult and past experiences have not been fully successful. Common problems mentioned by Sutherland *et al.* (1998) and Hall and Nahdy (1999) include:

- the identification of appropriate research topics - where research is organised with a crop and disciplinary bias, farmers' problems may be beyond the scope of the mandate of a project or programme,
- the requirement to alter the expected professional behaviour and roles of farmers and researchers,
- lack of training or experience amongst some researchers in the type of skills necessary for a participatory approach,
- the perceived validity of qualitative data and
- the limited amount of time available for researchers to spend in each community where research takes place. Establishing trust between farmers and researchers and understanding the relationships of power within the community is necessary for effective communication and for carrying out sensitive activities such as wealth ranking.

A change in attitude amongst researchers and development professionals, particularly senior research managers, is ultimately required for effective end-user participation in technology development (Baur and Kradi, 2001; Snapp *et al.*, 2003), yet contrary to this Hall and Nahdy (1999) state that the advocacy for participation has been prescriptive and often coercive, without sufficient attention to the impact of participatory methods or the receptiveness of institutional settings in which they are located. Where there is commitment and incentive for client orientated research, national agricultural research and extension systems will be more likely to develop ways of working which are economical and compatible with the realities of the institutional context of research and extension systems in developing countries. Sutherland *et al.* (1998), Walters *et al.* (1999) and Drechsel (2000) provide recommendations for increasing the quality of participatory technology development.

A strong national development policy commitment to resource-poor farmers is a key factor in stimulating and determining the successful integration of on-farm research within national agricultural research systems (Merrill-Sands *et al.*, 1991). The Ministry of Environment and Technology initiated commercialisation of the CSIR research institutes in 1996 and the institutes now have to generate a proportion of their income themselves (CSIR, 1999). Incentives for researchers to respond systematically to the needs of smallholder farmers appear to be lacking within the research system. Policy aimed at increasing payment by end users for research services may in theory increase the client orientation of research but is unlikely to favour smallholder farmers, and particularly the poorer farmers.

The new agricultural extension policy also focuses on finding alternative ways to finance extension and increase client orientation (Dulcire *et al.*, 1999; MOFA, 2001). Decentralisation of the extension services is currently under way in Ghana and may theoretically hold greater potential for increasing the client orientation of its services (MOFA, 2001). Budgets for extension services will eventually come from district assemblies, who could present an effective demand for more client orientated services. However, fiscal decentralisation has not yet taken place within MOFA and the ability of local government to respond to the needs of the rural electorate has not yet been proven. The new extension policy also aims to strengthen farmer cooperation through the formation of Farmer Based Organizations which could provide more effective demand for research and extension services, but which are currently very weak (Dulcire *et al.*, 1999). It also envisages that the private sector and NGOs will play a greater role in extension delivery. Public sector services will however, be maintained for small scale farmers, although there are no plans to alter the Training and Visit model beyond observing other 'experimental' approaches used by donor assisted projects (MOFA, 2001).

Ultimately, the extension services will not be effective where appropriate research outputs are not forthcoming. Furthermore, Dulcire *et al.* (1999) note that while farmers commonly articulate problems with markets and ability to access inputs, they may be less able to articulate their demand for technological change. Interaction with farmers is clearly critical to focus research on the needs of smallholder farmers, particularly for topics such as soil fertility where the visibility of the processes of cause and effect are limited, and farmers' knowledge of alternatives to traditional management is often limited.

6 AN INTEGRATED FRAMEWORK FOR PLANNING RESEARCH AND DISSEMINATION

This research found that livelihoods at the forest margin are diverse and complex. Farmers use a multiplicity of cropping patterns and have different sets of resource constraints and opportunities for crop production (Section 3.4.3). The outputs from soils research, such as the use of a mucuna cover crop in rotation with maize or the use of herbicide during land clearing, are therefore often only appropriate to a limited number of farmers and cropping patterns. So far the outputs from soils research have been more appropriate to sole maize cropping, commercial vegetable cultivation and male farmers than to other cropping patterns or to female farmers (Sections 4.2.2; 4.6.3; 5.4.2.2). Farmers who have the least access to fertile land are more frequently women, young men and settler farmers, rather than older male farmers. However, in addition to limited access to large areas of land these farmers are also variously constrained by the duration for which they have secure tenure, and limited access to cash and/or labour.

Until recently, there has been little participatory soil fertility research in Ghana and farmers' input into technology design has been particularly limited (Section 2.3; Section 5.4.2). Advocacy for participatory methods does not appear to have received strong support in national research organisations and there have been few incentives for researchers to carry out systematically client orientated research for smallholder farmers (Section 5.5). Within the extension services, formal linkages have recently been put in place to increase the feedback from farmers and extension to research. However, these have not so far been implemented effectively. Feedback from farmers to researchers, both during technology development, and more broadly, has therefore been limited so that research does not systematically consider the needs of smallholder farmers in technology design.

Farmers' livelihoods need to be given greater consideration in the design of soils technologies in order to produce technologies suitable for different cropping patterns and for farmers with different levels of access to resources. Furthermore, there is a need to design technologies that work under farmers' conditions of imperfect farm management and environmental control (Section 5.5). In this context, technology development would benefit from greater information about farmers' circumstances. More farmer participation in the design of soils technoloiges would be one way of achieving this. It could produce outputs better suited to the agro-

ecological and socio-economic circumstances of the farmers participating in the research (Douthwaite *et al.*, 2001; Sumberg *et al.*, 2003). However, the number of farmers taking part in participatory technology development is frequently limited, and there is no guarantee that they are representative of farmers more generally. Information about farmers' livelihoods and the diversity of farmers' circumstances in a broader context, could however, help researchers to understand how outputs from participatory research would benefit farmers more generally. This understanding could be used to ensure that research outputs were relevant to large numbers of farmers or to target research at marginalised groups of farmers, or farmers facing particular resource constraints.

In this chapter a framework will be presented which links agricultural research to rural livelihoods. The central objective of the framework is to facilitate information flow amongst different stakeholders involved in the design, dissemination and use of soil fertility management technologies. Within the framework, disaggregated information about land based livelihoods and access to resources is collected, collated and made available for use by researchers, policy makers and other decision makers. Researchers use this information in the development of technologies which are then presented in terms of their specific resource requirements. This facilitates analysis of the appropriateness of different technologies to livelihoods with different sets of resource opportunities and constraints.

Figure 6.1 shows how this could take place in Ghana at district, regional and national level through the use of livelihood and technology profiles. Livelihood profiles document resource access for disaggregated rural livelihoods and are collated at district level. Information from livelihood profiles is compiled into a livelihoods database at regional or national level. This database allows the user to compare resource access across farmers with different livelihoods. Researchers use technology profiles to present clear and comprehensive information about the resource requirements and potential benefits of different technologies. Technology profiles are assessed in terms of their relevance to livelihoods by comparing them with the data in the livelihoods database. Decision support tools are designed to support selection of technologies where both technology options, and livelihood opportunities and constraints are complex. Each element of this framework is outlined in more detail in the following sections.

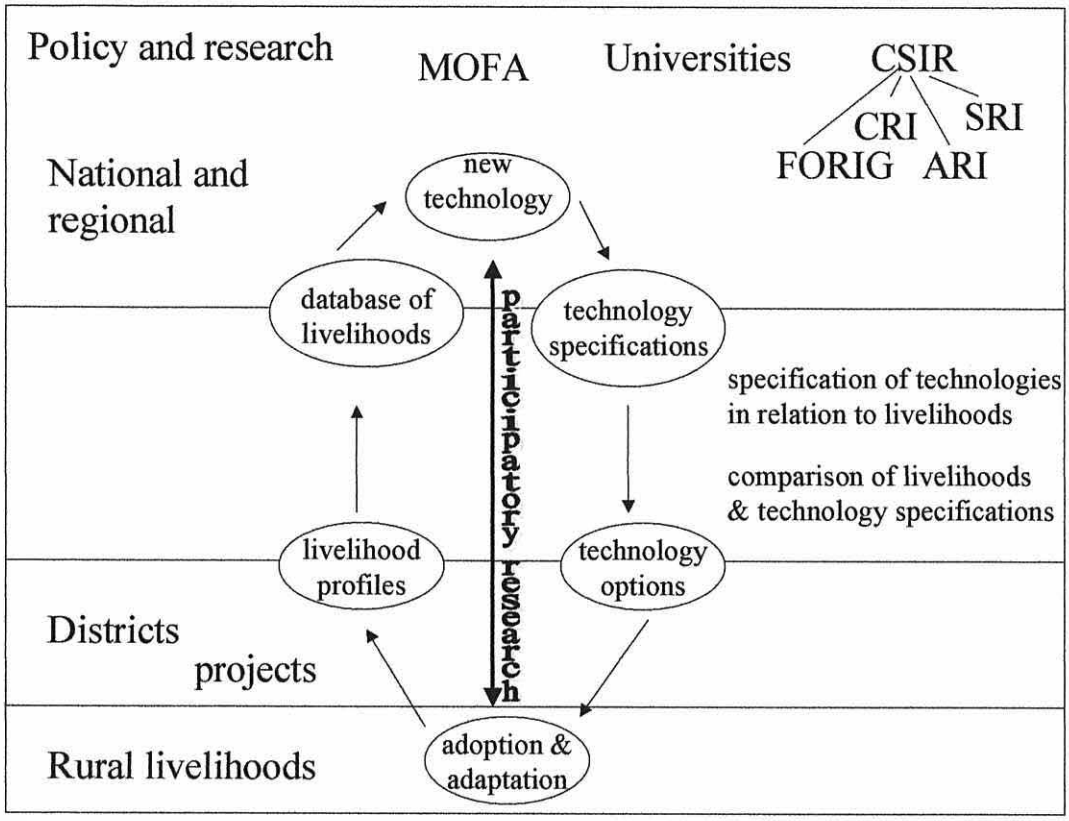


Figure 6.1 A framework for linking research and dissemination to rural livelihoods in Ghana.

6.1 Livelihood profiles

For some aspects of rural livelihoods there is little data available on farmers' access to resources. The labour required for a change in farming practices is a key example of this. Labour is difficult to measure (Section 2.1.3) making it difficult to estimate whether a change in labour requirements is compatible with farmers' other farming activities. In Ghana individual farmers commonly use multiple sources of labour with different farmers having access to different sources (Section 3.4.3.4). Only some sources of labour are remunerated in cash so that not all farmers will be able, or willing to use labour saving technologies that require cash outlay.

Disaggregated information about farmers' circumstances would enable researchers to design technologies using a more accurate picture of resource access. The combination of different resource opportunities and constraints can lead to different outcomes with respect to the potential of different technologies. For example, older men have more access to land and cash than younger men but rely more on hired labour (Section 3.4.3.4). They might be interested in technologies that reduce labour use but require cash outlay for other inputs, such as use of

herbicide. Younger men, on the other hand, use their own labour rather than hiring, but have less access to cash and land than older men. They might therefore be more willing to invest their own labour in a new technology, such as cultivation of an improved fallow, rather than increasing cash outlay. For older men, hiring additional labour to cultivated an improved fallow might be considered more risky than younger men's use of their own labour.

Many agricultural research and development activities carried out by governmental and non-governmental organisations in Ghana obtain information on aspects of rural livelihoods. Much of this information is contained in reports and other types of document which are not distributed or made widely available. Collecting such information is resource intensive and making it more widely available would improve the returns to data collection. Many agricultural development activities initiated by both governmental and non-governmental organisations operate through, or in close conjunction with MOFA at district level. MOFA's district directorates would therefore be well placed to consolidate information on rural livelihoods in different communities as part of on-going agricultural development work.

This research has suggested key aspects of rural livelihoods that need to be taken into account in the design of soils technologies and which are influenced by location and social differentiation (Section 3.5). Key issues with regard to access to labour, management ability, long and short term livelihood strategies, land use, cropping patterns, markets, duration and security of land tenure, cash income sources and perceptions of soil fertility that are hypothesised to influence the adoption of soils technologies have been outlined in Section 3.6. Access to key resources could be represented using livelihoods and land use diagrams. The method for drawing these diagrams has been outlined in Section 3.2. The focus of the diagrams is land use, making them particularly suitable for providing a summary of key resources in land based rural livelihoods. More detail on particular aspects of livelihoods could be presented in other ways which would include calendars to show cropping patterns and seasonal changes in the availability of key resources such as labour and cash. Guidelines would be required for disaggregating livelihoods and the collection and presentation of information to ensure that the qualitative data collected was of sufficiently high quality to be useful. For some aspects of livelihoods, most notably land tenure and access to labour, the exact information required would need to be carefully specified and the use of terminology would need to be standardised. Section 3.5.2 discusses the complexity of access to land in southern Ghana and suggests some indicators for distinguishing between locations experiencing different levels of land scarcity.

Livelihoods at each location would be disaggregated and a different livelihood profile would be created for each disaggregated social group. Gender, age, marital status, ethnic origin and length of residence in a particular location all influence access to resources, roles, responsibilities and livelihood strategies (Chapter 3). Not all of these attributes were relevant to every aspect of farmers' livelihoods, but all were influential in some way or another. These attributes did not capture all differences in livelihoods and access to resources, particularly for women farmers. Women are a heterogeneous social group in terms of resource access in southern Ghana (Baden *et al.*, 1994), although research by Quisumbing *et al.* (1995) did find female headed households significantly poorer than male headed households. Section 3.5.7 suggests that more research is necessary to achieve a greater understanding of women's livelihoods and the use of poverty indicators might further help distinguish social differentiation. Relatively consistent indicators of greater than average poverty and greater than average wealth appear to be emerging from other natural resource based livelihoods research in southern Ghana (Norton *et al.*, 1995; Brooke and Dávila, 2000). A simple method for identifying individuals at the extreme upper and lower end of the poverty scale could be developed and tested from these.

6.2 A livelihoods database

Livelihood and land use diagrams, and other forms of livelihood data, could be developed initially as paper based resources. These could then be entered into a computer to facilitate the sharing of information. Livelihood profiles collected from the districts would be passed on to the regional and national headquarters of MOFA. They would then be compiled and organised in a database which would be used by researchers, development workers and policy makers. The remainder of this section provides a specification for the design of such a database.

A key requirement would be the ability of the database to be easily updated with new livelihood profiles as these became available as part of on-going research and development activities. Furthermore, because livelihoods change over time, livelihood profiles would have a limited lifespan. Users would need to be aware of the validity of the information in the database. Including the date when the data was collected or last verified would be one way of achieving this. Where necessary, livelihood profiles could be validated in the field and the database updated.

The database would be fully searchable. Users would be able to retrieve information on the livelihoods of individuals belonging to a particular social group, such as young women, or living in a particular geographical or agro-ecological region. They would also be able to use

the database to find the livelihoods that matched a specific set of resource opportunities and constraints.

The information required for the database would include:

- categorisation of livelihood profiles according to location and social attributes such as gender, age, marital status, ethnic origin and length of residence in a particular location,
- categorisation of different locations according to their market links for different crops, agro-ecology, off-farm employment opportunities and settlement and migration patterns,
- information on land use, cropping patterns, crops grown, livelihood strategies and access to land, labour and cash for each livelihood profile, with some quantification as to the extent to which these were applicable to the individuals defined by the livelihood profile,
- a facility to estimate the number of individuals associated with a particular set of resource opportunities and constraints,
- the ability to view individual livelihood profiles.

Detailed information on aspects of land use and crops grown would be required. This would include type of land, cropping patterns, form of tenure, and farmers' perception of fertility. Detailed information on crops grown for sale would include information on the seasonality of production, time of sale, market links and individuals' decision making power over the disposal of proceeds from cash sale. Information on land use and farming activities would take into account the associations between different crops and cropping patterns. For instance, land might be considered infertile for cocoa but not for food crops, farmers might rent land next to a water body for dry season tomato but not rent land for other crops. Information on access to labour would include sources of labour, presence of seasonal labour constraints, and access to and dependency on hired labour.

6.3 Technology profiles

Researchers would produce technology profiles for individual technologies to specify as clearly and comprehensively as possible the requirements for the technology to be effective, and its potential benefits. As much information as possible would be included in these profiles so that individual technologies could be evaluated for their relevance to the livelihoods of different groups of smallholder farmers.

Four main areas would be covered by the technology profiles. Firstly, information would be required on the demonstrable benefits of the technology. Common benefits are likely to be yield increases, reductions in labour requirements and the production of other products such

as fodder. They would also include information on environmental services such as increases in soil fertility or a reduction in soil erosion. However, farmers are unlikely to be persuaded by a technology on these grounds alone (Tomich *et al.*, 1998; Bunch and Buckles, 1998). Secondly, information would be required on the crops and cropping patterns for which the technology was effective. Thirdly, the technology profile would state the inputs required for the technology to be effective in producing the stated benefits. These are likely to include inputs associated with individual technologies as well as labour, cash, land, agro-ecological requirements (such as rainfall) and knowledge or farmer training. Finally, and very importantly, information would be required on the way in which changes in the quantity and timing of input use influenced the outcome of the technology i.e. its benefits. This last requirement draws on Reece and Sumberg's (2003) concerns that technologies have been designed for farming systems which assume a level of precision in management and control of the environment that is not available to smallholder farmers in developing countries. It would enable an estimate of the precision required for the technology to be effective, and hence how risky it would be for smallholder farmers who have incomplete control over the environment and their own resources.

Researchers might need guidance in developing technology profiles to produce systematic and comprehensive accounts. A set of questions that could be considered in the production of technology profiles for soil fertility management technologies in Ghana is provided in Table 6.1. A set of responses for relay cropping of late maturing mucuna (*Mucuna pruriens*) into major season maize is given in Table 6.2. A technology profile would additionally include a cropping calendar featuring seasonal rainfall, land use, activities and expenditures associated with the technology.

The information contained in the technology profile would be specified as fully and quantitatively as possible for the environmental domain for which it was relevant, in this case the forest margin in southern Ghana. For instance, in Table 6.2 yield increases have been quantified as 30 – 70% higher for maize following cultivation of mucuna but the original grain yields by which these were estimated are not, but should, be given. Additionally, local indicators as well as scientific ones should be included for quantitative and qualitative measurements so that effective comparisons could easily be made between the technology and the circumstances of farmers. For instance, acres are used as well as hectares in Table 6.2. However, no local indicator of 'low soil fertility' or other soil parameters are given. Providing them would increase the utility of this information. It would enable a wider range of individuals to use the technology profiles by lowering the level of technical knowledge required to be able to understand them and apply them to real situations.

Table 6.1 Questions to guide production of technology profiles for soil fertility management technologies in Ghana

Attribute of technology	**Questions**
Crops	
Target crops	Which crops will the technology work on effectively? For which crops is it unsuitable?
Cropping patterns	What cropping pattern is necessary for the technology to be effective?
Input requirements	
Technology inputs	What inputs related to the technology are required? e.g. agrochemicals and sprayers, manure, seed How much of each input is required? When should they be obtained? How can they be obtained? What is the cost of obtaining them in terms of both the cost of the inputs themselves and getting access to them? (e.g. a trip to the nearest town to make purchases)
Labour	What activities (requiring labour) are necessary to implement the technology? When must they be carried out in order for the technology to be effective? Within this range, what impact will the timing of these activities have on the effectiveness of the technology? How will these activities be carried out? Are they gender specific, and are they likely to require hired labour in order to be carried out at the correct time?
Cash	What cash inputs are required for the technology: - for the technical inputs themselves? - to obtain the technical inputs? - for labour? When is cash necessary to obtain them?
Land	What type of land and soil is necessary for the technology to be effective in terms of: - topographical position? - slope? - texture? - fertility? What impact will differences in soil attributes, especially fertility, have on the effectiveness of the technology? Over what period of time does a farmer require secure access to land in order - to be able to implement the technology? - to benefit from the technology? What impact will extending or shortening this time period have on the benefits that the farmer obtains from the technology?
Agro-ecological inputs	When is rainfall or soil moisture required for the technology to be effective? Within this range, what impact will the timing of rainfall or moisture availability have on the effectiveness of the technology? Is the technology associated with any pest or disease problems that could influence its effectiveness?
Farmers' knowledge	What are the minimum knowledge or training requirements for the technology to be effective?
Potential benefits	
Crop yields	For which crops will the technology result in changes in yield? Over what range will yields differ from standard farmers' practice? What factors influence this range? Will the technology alter the time when crops are harvested, and if so, what impact will this have on household food security and crop sales?

Table 6.1 continued

Attribute of technology	Questions
Labour	Will the technology result in any positive modifications to labour requirements for the current or subsequent crop? If so, what activities are involved and how is labour usually sourced for these activities? By how much will labour requirements decrease?
Additional products	Will the technology produce any additional products? What are these products? When are they harvested? What processing will be required before they can be used? Will harvesting these products have any negative influence on the effectiveness of the technology?

Table 6.2 Technology profile for relay cropping of late maturing mucuna (Mucuna pruriens) into major season maize

Attribute of technology	Responses for relay cropping of late maturing mucuna (*Mucuna pruriens*) into major season maize
Crops	
Target crops	Technology effective with maize Not suitable for perennials or low growing crops
Cropping patterns	Maize monocrop – mucuna is relay cropped into maize and the next food crop is planted the following year.
Input requirements	
Technical inputs	Mucuna seed – long duration variety at a rate of 16 – 20 kg ac^{-1} (40 – 50 kg ha^{-1}) or 2 to 3 seeds per hole. Seed can be obtained any time prior to planting in June or July from the Sedentary Farming Systems Project in Sunyani or the Crop Research Institute at Kumasi or from the small numbers of farmers using it in the Brong Ahafo region. Cost of obtaining seed is difficult to estimate and depends on the location of the farmer, but small quantities of seed can currently be obtained at no cost. Seed may then be saved for use the following year.
Labour inputs	Activities requiring labour: - Weeding of maize prior to subsequent planting of mucuna - Planting of mucuna at least 60 days after planting maize at tasseling from mid June to mid July (for Brong Ahafo) - One weeding of mucuna may be necessary before canopy establishment - Harvest of some seed during the dry season for use the following year Influence of timing of activities on effectiveness of technology: - Establishment is reduced by not weeding prior to planting mucuna - Planting mucuna too early (prior to 60DAP) results in too much competition with the maize, planting too late (after mid July – Brong Ahafo) reduces the chances of good establishment of the mucuna - Weeding mucuna is dependent on establishment of mucuna which in itself is dependent on seed rate used and plant spacing of mucuna Activities are not gender specific.
Cash inputs	Cash may be necessary prior to July to obtain seed (although seed probably costs nothing). The need to hire labour for additional activities will depend on the farmer's circumstances.

Table 6.2 continued

Attribute of technology	Responses for relay cropping of late maturing mucuna (*Mucuna pruriens*) into major season maize
Land inputs	Mucuna is sensitive to waterlogging and this reduces biomass production. Biomass production and nodulation are sensitive to phosphorus. Dry matter production is less than 5 t ac^{-1} (2 t ha^{-1}) where soil phosphorus is less than 5 parts per million Soil pH should be greater than pH5, lower levels reduce rooting depth and biomass production. Secure land access is required for one year to implement technology and two years (two major seasons) to benefit.
Agro-ecological inputs	Mucuna must receive sufficient rainfall between July and November for biomass production. Full canopy establishment occurs at around 8 weeks after planting. More precise rainfall requirements are unknown for adequate biomass production. Not associated with known pest or disease problems
Farmers' knowledge inputs	Some training required – as this is a novel technology for Ghana demonstration is likely to be required
Potential benefits	
Crop yields	Any crop grown after mucuna should benefit from the biomass produced. Maize yields have been raised by 30 – 70% in Brong Ahafo Yield increases are influenced by original soil fertility, and mucuna biomass production i.e. the lower the initial soil fertility and baseline maize yields, the greater the potential for yield increases following mucuna.
Labour	Labour reductions for: - clearing land for subsequent crop – no clearing or burning is necessary as the following crop is planted through the mucuna mulch. However, some farmers may fear snakes hidden in the mulch. - weeding subsequent crop – one weeding less may be required
Additional products	Mucuna seed can be eaten in small quantities following processing to detoxify. Seed and dried biomass can be fed to livestock. Use of biomass as livestock feed may reduce soil fertility benefits to subsequent crop.

Sources of information: Loos, 2000; University of Wales, Bangor, 2003a, 2003b

6.4 Evaluating the technology options for farmers with different sets of resource opportunities and constraints

Donor agencies such as DFID frequently aim to carry out or support equitable agricultural research and development work. As such they are often concerned that research benefits the poorer sections of the communities in which work is carried out, or that their activities have a positive impact on women's livelihoods. Similarly, the Government of Ghana is aware that agricultural research, extension and policies fail to reach all groups of farmers equally. The National Soil Fertility Management Action Plan states that despite women's significant contributions to the agricultural sector, they have been bypassed by agricultural policies and programmes (MOFA, 1998). The Government of Ghana's Poverty Reduction Strategy is part of a more general objective to raise Ghana to the status of a middle income country by the

year 2020 and agricultural development plays an important role in this (Government of Ghana 2000).

Evaluation of technology profiles in terms of specific groups of target farmers could clarify whether, and how, different technologies are appropriate to different groups of farmers. The livelihoods database could be used during technology development to identify how a technology matched the constraints and opportunities of different livelihoods. Researchers might aim to develop technologies that would be appropriate to a large range of farmers. Alternatively they might be attempting to reach marginalised groups such as women, or to target a particular crop such as maize.

Where a lack of technologies was evident for a particular social group, disaggregated information about farmers' livelihoods could help researchers and policy makers in decision making. Different scenarios are possible. Firstly, it might be the case that no technologies had yet been devised, or else adapted to Ghanaian circumstances for farmers with a particular set of resource opportunities and constraints simply because the research in this area had so far been limited. For example, there are many leguminous cover crops worldwide, but only a narrow range of species have been experimented with in Ghana in conjunction with a narrow range of crops and cropping patterns. Further research might produce relevant technologies if the requirements of this group of farmers were considered at an earlier stage in the research process.

Alternatively, it might be the case that a technology exists, but that a group of farmers faces a key constraint to adopting it which could be addressed by another agricultural intervention. For instance, maize yields might be raised using inorganic fertiliser, but this might only be profitable if farmers were able to delay maize sale until prices had risen. Maize storage would require appropriate post-harvest technology to minimise losses.

A third situation could arise where technology adoption would only occur for a group of farmers when agricultural policy issues had been addressed or other agricultural changes had been made at a regional or national level. Examples are changes in the farmgate price of cocoa, policies or interventions to reduce the cost of imported agro-chemicals, agricultural policies promoting the integration of crops and livestock accompanied by interventions to support the recycling of animal manure from large scale commercial farms such as intensive poultry units, and support for integration into world markets for organic producers which could bring higher prices for farm products and encourage organic soil management.

Finally, it might be considered that indirect non-agricultural interventions and policies might have a greater impact on rural livelihoods and soil productivity than more direct interventions. Examples are improvements in infrastructure to increase the market integration of rural areas, better health care and education, and labour saving devices for women such as more boreholes and food processing devices which could free up women's time for farming activities.

6.5 Evaluating technologies in terms of their relevance to end users

The livelihoods database could be used to evaluate the potential of different technologies and guide decision making about the allocation of resources for research and development activities. The resource requirements and potential benefits of a single technology, as expressed in a technology profile, could be compared with information on farmers' opportunities and constraints in the livelihoods database. This would suggest the number of farmers to whom the technology was appropriate, and their characteristics. The results of this evaluation would suggest whether further research on the technology was necessary or desirable, or whether the technology had little potential (Figure 6.2).

Technologies already tried and tested in Ghana could be evaluated to determine their recommendation domain. Where technologies were considered to have some adoption potential extension material would be produced, and the technology would be disseminated more widely. During the course of evaluation, additional requirements for successful technology adoption might be identified, e.g. the availability of cover crop seeds, and these requirements could be considered in plans to extend the technology. Technologies that had only been partially specified in Ghana, or else tested in other parts of Africa, but not in Ghana, could also be evaluated to determine whether it was worthwhile to invest research resources in developing them further. The resources required could be evaluated in terms of their potential impact on different groups of farmers and in consideration of research and development priorities.

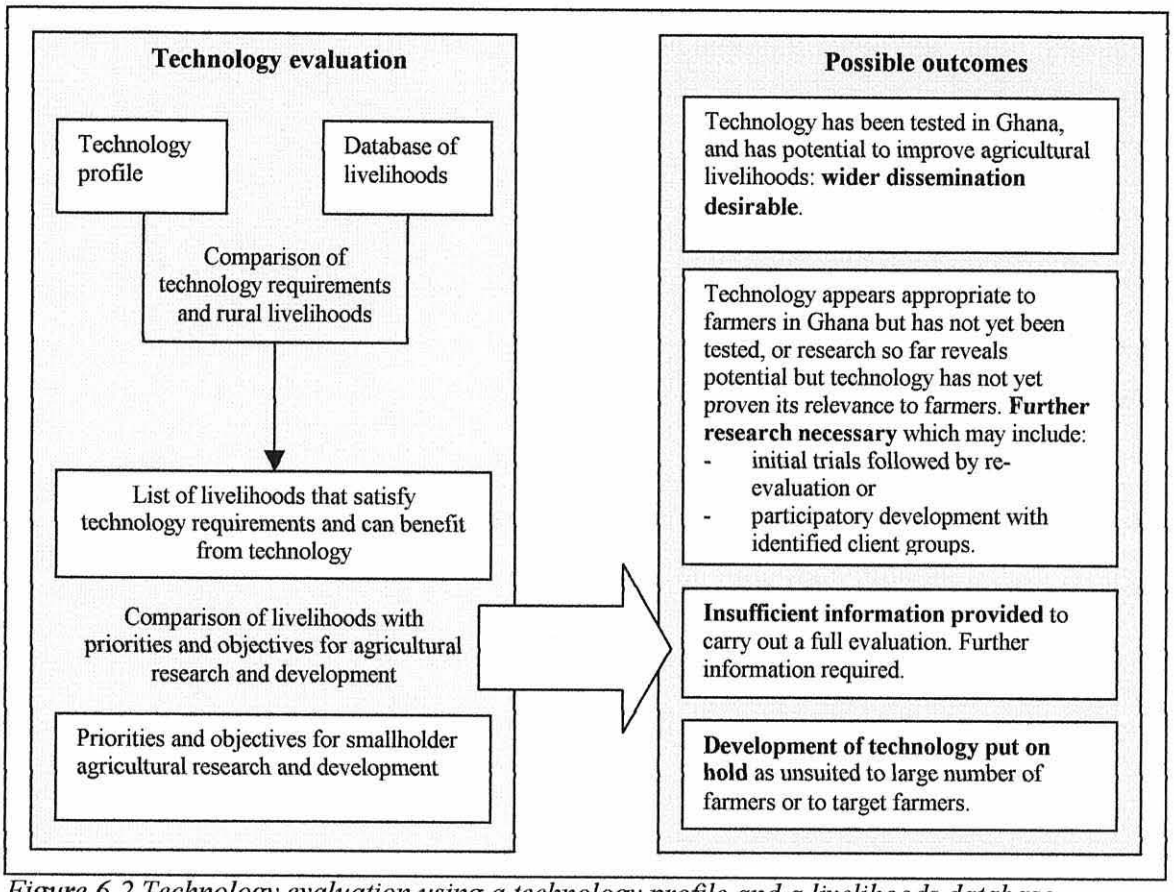


Figure 6.2 Technology evaluation using a technology profile and a livelihoods database

6.6 Development and use of decision support tools

Table 6.1 and Table 6.2 illustrate how a complex, and sometimes precise, set of environmental and socio-economic conditions may be necessary for a technology to be effective in delivering benefits to farmers. The effectiveness of relay cropping mucuna with maize is dependent on:

- obtaining the mucuna seed,
- planting the mucuna on clean ground for good establishment i.e. weeding maize prior to planting,
- planting the mucuna sufficiently early i.e. before mid July, for good establishment,
- reducing competition with maize by planting the mucuna at least 60 days after planting maize,
- sufficient rainfall in the minor season for production of mucuna biomass,
- access to the land for at least two years,
- soil with adequate phosphorus (greater than 5 parts per million), and a pH greater than five.

Furthermore, in addition to being able to satisfy these criteria, the extent to which the technology can raise yields is dependant on the initial fertility of the soil, with higher

percentage yield increases occurring for the following crop on soil with low initial fertility. Relay cropping of mucuna is also only suitable in conjunction with maize and prevents the cultivation of other intercrops.

Other ways of integrating legumes into cropping patterns also exist (University of Wales, Bangor, 2003a). Table 6.3 shows four different ways of integrating cover crops into maize cropping patterns in Ghana suitable for areas with biannual rainfall patterns. A short duration variety of mucuna can be planted in the minor season after maize harvest. Mucuna can be planted in the major season, and followed by maize in the minor season. *Canavalia ensiformis* can be intercropped in plantain based intercropping systems. These are all different technology options and each one has its own set of resource requirements and potential benefits. Making appropriate recommendations to farmers requires consideration of the appropriateness of different options to different farmers.

Table 6.3 Technology requirements for four different ways of integrating cover crops into maize cropping patterns from LEGINC (University of Wales, Bangor, 2003a)

Legume integration technology	**Technology requirements**					
	Food cropping pattern	**Duration of secure tenure**	**Absence of bush fires in the dry season**	**Maize planting date**	**Cover crop planting date**	**No. weedings required for cover crop establishment**
Major season mucuna followed by minor season maize	Sole maize	1 year	No	August to September	March to April	1 or 2
Major season maize relay cropped with long duration mucuna	Sole maize	2 years	Yes	March to April	Mid June to mid July	1
Major season maize followed by short duration mucuna	Sole maize	2 years	Yes	May	Mid August to mid September	1 or 2
Major season maize intercropped with a slow growing cover crop e.g. *Canavalia ensiformis*	Maize relay cropped with plantain	2 years	Yes	March to April	April to June	1 or 2

However, matching complex technologies to livelihoods and cropping patterns which are in themselves diverse and complex, is likely to be challenging for the agricultural extension services. Results of the case study in Section 5.4.3 suggested constraints in the provision of extension services to farmers at district level. Extension agents were able to present packaged technologies to farmers, but lacked analytical and problem solving skills to assess a farmers' situation and provide technical recommendations accordingly. Extension agents were also overburdened under the Unified Extension System which expects them, unrealistically, to be conversant with all agricultural topics. In conjunction with this, there were low levels of

agricultural information resources available at the district level for extension agents to draw on. In the absence of fiscal decentralisation and with very limited budgets, many of MOFA's district offices have continued to carry out directives issued from above, with minimal information gathering of their own. However, once decentralization of the extension services has been fully implemented, decision making will become an essential requirement.

Decision support tools could be designed which would contribute to more effective extension provision by matching of the needs of rural producers to the requirements of available technologies. Use of livelihood and technology profiles could also facilitate feedback to researchers by providing information on the extent to which technologies address the requirements of rural producers, their adoption and the factors which constrain adoption amongst different groups of farmers.

At the most basic level of analysis, livelihood profiles could be compared with technology profiles to target dissemination activities. This could be done in Ghana by the district director of agriculture and his extension officers responsible for supervision of the extension agents. MOFA's technical specialists from the regional directorates could provide technical backstopping as necessary. The analysis would enable district extension offices to target technologies at particular groups of farmers, and to coordinate provision of information with other necessary services such as advice on post-harvest technology or provision of seed.

Decision support tools could also be developed to offer a more sophisticated means of comparing technology requirements and farmers' circumstances. Such tools could incorporate information about the potential benefits and essential requirements for technologies to be effective. They might also incorporate location specific information such as climate or soil data. They would then elicit essential information about a farm or farmer, and using expert rules, match this information to the technologies available in order to provide management recommendations. Decision support tools would be particularly useful where a large number of technology options exist, which when fully specified have complex sets of requirements, or else where livelihoods have diverse sets of opportunities and constraints. Under these circumstances, decision support tools could lessen the requirement for extension agents to analyse complex livelihoods and farming systems, and to be familiar with the requirements of a large number of different technologies.

Decision support systems have in the past facilitated learning by their end users so that continued use decreases over time, and this may be one of their most important functions (McCown, 2002; Walker, 2002). In this case, iterative use of a decision support tool could

help extension agents to become more familiar with different technology options, and how these were suitable for farmers with different sets of resource endowments. Such decision support tools need not be sophisticated computer programs. Where simple sets of expert rules are involved, they can be captured using decision trees which can be presented as paper based resources.

6.6.1 Development of LEGINC: a decision support tool for incorporating legumes into cropping patterns in Ghana

A decision support tool was produced during the course of this research to support selection of legumes and ways of incorporating them into farming systems. It was developed as a piece of computer software and named LEGINC (Legume Incorporation) (University of Wales, Bangor, 2003a). Within the tool there is information about attributes of 113 tropical herbaceous and shrub legume species and 18 different 'technologies' i.e. ways of integrating legumes into cropping patterns. The information about the legume species was obtained from LEXSYS (Legume Expert System), a legume database developed by the International Institute of Tropical Agriculture (IITA) for West and Central Africa.

Within LEGINC, the user is asked a series of questions. The list of species and technologies is refined based on the user's responses. This is done using a set of expert rules designed to capture known, critical biophysical and socio-economic differences in farmers' circumstances that will influence the appropriateness of different technologies and legume species (Figure 6.3).

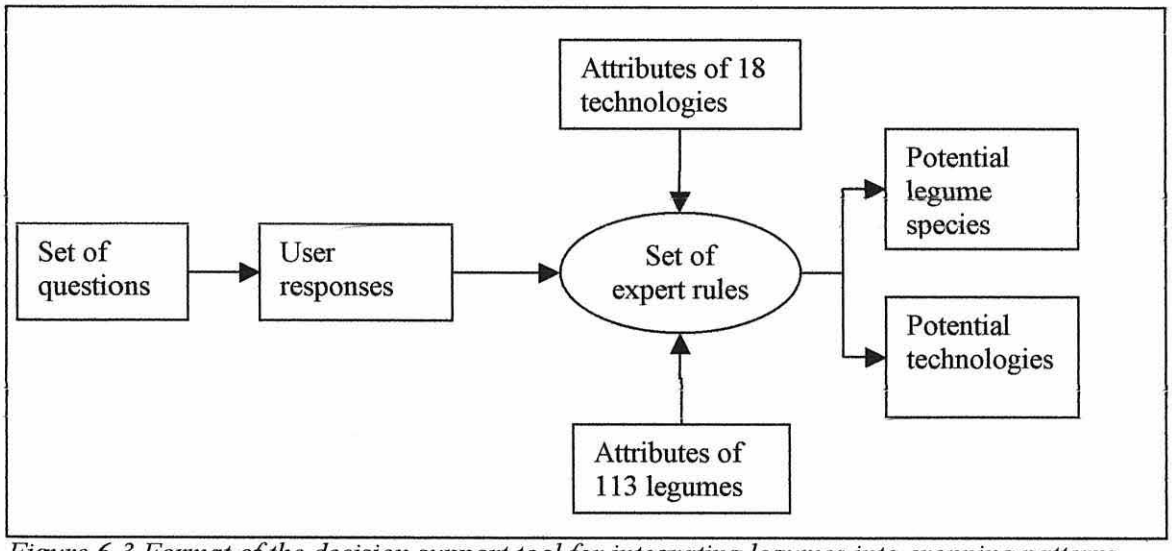


Figure 6.3 Format of the decision support tool for integrating legumes into cropping patterns in Ghana

The tool was customised to the situation of farmers at the forest margin in Ghana drawing on lessons learnt by the Crop Research Institute, Sedentary Farming Systems Project, Integrated Food Crop Systems Project, on-going research by the University of Wales, Bangor and other legume research and development activities (Section 5.1). The questions and rules used within the tool were designed to:

- match legumes to site conditions both in terms of general climatic conditions and field level conditions,
- identify legumes and technologies that would provide user specified benefits,
- identify legumes and technologies that could be integrated into existing cropping patterns and
- match management of the legume and technology to farmers' labour and management constraints.

Integrating a legume into farmers' land use and cropping pattern required the most complex set of questions and rules. For example, in order to integrate a legume with maize, the other crops intercropped or grown in rotation with maize, the duration of secure land access, the risk of bush fires, maize planting time and the time when labour is available to cultivate the cover crop must all be considered. Expert rules which drew on attributes of technologies and attributes of legumes were used to produce a list of potential legumes and technologies. For example, legume species suitable for intercropping with maize and plantain for weed suppression, were restricted to species which were shade tolerant, had a spreading growth habit and were either perennial, self seeding or otherwise suited to simultaneous intercropping on plantations. In another example, where maize is cultivated without other crops, and the farmer has access to land for one year only, or else if the farm is likely to be burnt by bush fires during the dry season, then the tool suggests cultivation of a short duration legume in the major season followed by cultivation of maize in the minor season.

6.6.2 Using livelihood and technology profiles to provide a context for feedback to researchers

Decision support systems have been successful in stimulating discussion of alternative crop management practices, particularly where the tools involve farm simulations or scenario analysis (Carberry *et al.*, 2002; Hearn and Bange, 2002). In the Ghanaian context, where greater communication amongst farmers, extensionists and researchers is desirable, stimulating discussion between different stakeholders would be particularly valuable. Researchers could design decision support tools using their knowledge of technology

requirements to produce a set of expert rules which captured the key requirements for a technology to be effective. Extensionists would use the decision support tools to provide recommendations to farmers. They would then provide feedback to researchers on whether farmers acted on the recommendations, and on the impact of these recommendations on farmers' fields, thus providing an opportunity for discussion and evaluation.

In addition to decision support tools, technology profiles could also be used to stimulate feedback from farmers, via extension agents, to researchers. Specifying technologies as clearly as possible and providing a range of environmental and management conditions over which they should be effective would provide a context for extension agents to provide feedback. During interaction with farmers extension agents would receive feedback on whether a technology was effective, and how effective it was. A clear technology profile would help extension agents to analyse the performance of the technology. Comparing the farmer's implementation of the technology with a set of requirements specified in the technology profile would reveal whether the minimum requirements had been met by the farmer. Where these requirements had not been satisfied, this would indicate that the technology was unsuitable for the farmer. Where the requirements had been satisfied, but the performance of the technology was below expectations, feedback could be provided to researchers giving the potential reasons for the difference in performance and technology profiles could be updated giving consideration to this information.

6.7 Conclusions

This research has shown that the livelihoods of smallholder farmers at the forest margin are not given sufficient consideration in the design of soils technologies, resulting in the production of technologies that are only suitable for a limited proportion of the farming population. There is no effective means of focusing research and dissemination on farmers with different circumstances. To address this need, this chapter has presented an integrated framework for linking agricultural research to the disaggregated livelihoods of smallholder farmers. The framework does this by showing how information about rural livelihoods could be collected, organised and passed on to research. At the same time researchers would provide clear outlines stating the requirements for a technology to be effective, which included socio-economic as well as bio-physical factors. This facilitates clearer analysis of where technologies are likely to be appropriate to rural livelihoods.

The framework makes use of a number of tools, or formal methods, to organise information about livelihoods and technology requirements. The tools suggest firstly, what information

may be relevant when developing soils technologies with farmers. Secondly, they suggest a way of organising that information so that it is accessible to others. As such, they are not tools that can be used mechanistically, but instead they facilitate applied analysis of information. Three of the tools - knowledge bases developed in Ghana (Section 0), land use and livelihoods diagrams (Section 3.2) and matching technology profiles to rural livelihoods, were presented to groups of researchers, extensionists and students at a series of workshops in Ghana in June, 2001 (Moss and Sinclair, 2001). It was evident that the tools were quite novel to the participants and made them think in ways that they were not accustomed to. The tool for matching a technology profile to rural livelihoods was considered the most useful. Where data is qualitative, and where multiple factors may, or may not, have some influence on the appropriateness of research outputs to rural livelihoods, formal methods can help researchers and development workers to carry out a more systematic analysis which can result in consideration of aspects of technologies, such as labour requirements, that might not previously have been considered.

If the framework presented here were to be adopted in Ghana, it would require considerable institutional support at a senior level to be effective in influencing decision making about agricultural research and dissemination. Incentives for carrying out client orientated agricultural research would be required for sustained institutional adoption. Some of the tools that have been suggested, notably the livelihoods database, would require further development and testing. Capacity building would also be required amongst some researchers and extensionists to reorientate them towards a livelihoods approach.

7 CONCLUSIONS

The final chapter of this thesis presents a synthesis of the research findings and their implications for agricultural technology development.

The outputs of soils research in Ghana

Farmers in southern Ghana have traditionally used fallowing to restore soil fertility. Long duration natural fallows in the humid tropics can effectively supply large quantities of organic matter so that there is little need for alternative means of soil fertility management (Nye and Greenland, 1960). However population density has increased, bush fallows have shortened and this has been associated with a reduction in soil fertility and crop yields (Amanor, 1993; Quansah *et al.*, 2001; Zimmermann, 2001).

Soils research and dissemination activities in Ghana have, until recently, focused on the use of inorganic fertilisers which were subsidized until 1992 (Bonsu *et al.*, 1996). Since the loss of subsidies, and in conjunction with the low market price and large seasonal fluctuations in the price obtained for staple commodities, it has generally been recognised that inorganic fertiliser is not economical for all but the most highly intensive commercially orientated smallholder crops, which account for a relatively small proportion of cultivated land (Bonsu *et al.*, 1996; MOFA, 1998). Soil fertility research and extension, particularly low external input and nutrient management approaches for smallholder farmers in southern Ghana, have received little priority until recently (MOFA, 1998; Section 2.3). Soils research has therefore produced few outputs for smallholder farmers in southern Ghana.

Understanding farmer investment in soil fertility management

The intensification of land management is not an automatic process that follows from increases in population pressure on cropped land (Boserup, 1965). It is linked to larger changes in other sectors of the economy - to the dynamics of labour supply and demand on-farm and off-farm, the market demand for agricultural commodities and the development and accessibility of technologies to intensify land management (Ruttan and Hayami, 1998).

Adoption studies of alley farming and cover crops, considering their specific biophysical and socio-economic requirements, illustrate the multiple conditions that may be necessary for smallholder adoption of complex technologies (Section 2.2). Alley farming with Leucaena

leucocephala or Gliricidia sepium has a limited recommendation domain in West Africa, even without consideration of the labour intensive nature of the technology and limited potential for yield increases (Sanchez, 1995; Whittome *et al.*, 1995; Dvorák, 1996). Adoption and disadoption of the widespread mucuna maize rotation in the hills of northern Honduras illustrates the dynamic nature of livelihood strategies and the spatially and temporally specific set of conditions for widespread adoption of some low external input technologies to take precedence over the use of purchased inputs (Buckles *et al.*, 1998; Neill and Lee, 2001).

In general, and as illustrated by these cases, farmers' willingness to invest in soil fertility is time and location specific (Scoones and Toulmin, 1999). A complex set of biophysical, socio-economic and institutional factors influence the opportunity costs of land and labour. Simple hypotheses based on increasing population pressure and declining length of bush fallows are insufficient to predict intensification of land management. Investment in soil fertility takes place in the context of broader livelihood strategies which include both on-farm and off-farm income generating opportunities and markets for agricultural products.

Diversity in land based rural livelihoods at the forest margin in Ghana

Field based research was carried out at five field sites at the forest margin in southern Ghana which differed broadly in terms of population density, agro-ecology and market access. Farmers' livelihoods and access to key agricultural resources were assessed at each site giving consideration to differences in the social attributes of individual farmers in terms of gender, age, marital status, origin and ethnicity. Agricultural activities for food and income generation were diverse, both between and within sites (Section 3.4). Location influenced broad differences in amount and distribution of rainfall, inherent land and soil properties, the occurrence of annual bush fires, the presence of valley bottom lands offering a niche for specialised cropping activities, and opportunities for the sale of crops and off-farm employment. The social attributes of individual farmers influenced their access to productive resources and their role in crop production.

Farmers' knowledge of soil fertility

A Knowledge Based Systems approach was used to assess local knowledge of soil fertility management (Section 4.1). The research found that farmers had knowledge about the properties of different types of land and soil and the ecology of different fallow and weed species (4.4). Knowledge distribution was significantly influenced by past experience with particular soil fertility management technologies, most notably for inorganic fertiliser, herbicide and animal manure. Farmers had some knowledge of nutrient cycling but lacked

knowledge of below ground processes which were difficult to observe, and explanatory knowledge of soil pests and diseases. Detailed knowledge of the practical use of animal manure was generally limited amongst all farmers due to infrequent use. These gaps in knowledge suggested that farmers could benefit from greater understanding of some subject areas, but did not suggest that lack of knowledge was a major factor preventing widespread adoption of the soils technologies that had been promoted by the extension services, or that educating farmers would be sufficient to bring about changes in behaviour.

Evaluation of soil management technologies in terms of livelihoods and local knowledge

The diversity in agricultural practices and access to resources amongst farmers entailed that soils technologies were only adopted for particular crops or cropping patterns and were only appropriate to a limited number of farmers. This could be demonstrated for a range of soil fertility technologies which have been developed or tested in Ghana and which included inorganic fertiliser, animal manure, retention of vegetation biomass during land preparation and cover crops. Local knowledge also explained some aspects of farmers' behaviour (Sections 4.6; 5.4.2.2).

Appropriate cropping patterns and other resource requirements for the majority of these technologies made them more suitable for male farmers than for female farmers. Use of inorganic fertiliser, or of manure as a substitute, on highly commercialised crops, was associated more with male than female farmers as was the use of herbicide. In the medium to long term, increasing integration between livestock and crop farming will be desirable for increasing nutrient cycling at the forest margin in Ghana. However, in the short to medium term, integrating legumes into cropping patterns could contribute to nutrient cycling where farmers do not have access to other nutrient inputs, and this may have wider application to female farmers. However further research is necessary to target a wider range of cropping patterns at the same time as reducing the labour requirements of cover crop technologies. Tenure security is also required and may limit adoption by tenant farmers who are frequently settlers. Lack of large scale adoption is not in itself a problem where soils research outputs are highly appropriate to farmers with very specific sets of resource endowments. However a research strategy which considers the impact of research outputs may be desirable to ensure that resources are used effectively and that outputs are applicable to disadvantaged groups.

Technology development and dissemination

Development of cover crops technologies in the Brong Ahafo region was used as a case study to assess the generation and transfer of knowledge within the agricultural research and extension system. This case study demonstrated the fact that the involvement of smallholder farmers in formal agricultural research has so far been limited (Section 5.4.2). Although short term soils projects carried out in collaboration with international research partners have recently increased farmers' participation in technology development, end user involvement in soils research has more generally been limited. Adherence to a linear model of technology development and dissemination has resulted in little farmer participation in the design stage of technology development. Furthermore, formal linkages that were put into place to increase feedback from farmers to researchers and to make research more accountable to its end users require strengthening. In addition, recent policy aimed at commercialisation of the research institutes under CSIR provides more incentive for researchers to collaborate directly with the private sector and large-scale farmers rather then smallholders or farmers' organisations (Dulcire *et al.*, 1999; MOFA; 2001).

The results of the local knowledge survey revealed that farmers' experience of using a technology was more important in determining their level of knowledge than contact with the extension services (Section 4.6.9). However the survey did provide some evidence that the extension services had an impact on farmers' practices. The case study of cover crop technology development found that the transfer of outputs from soils research into farmer recommendations and their dissemination was often slow (Section 5.4.3). In the absence of the functioning of formal linkages between research and extension, district extension services would benefit from a more pro-active approach to acquiring new agricultural information. The research also identified problems at the level at which research outputs were communicated to farmers. Extension agents lacked the skills to analyse farmers' circumstances and advise them accordingly, and preferred to present packaged technologies to farmers. They were unrealistically expected to be conversant with all agricultural topics, yet information resources available at the district level were limited.

However, overall, in the absence of outputs from soils research, extension messages had rarely focused on soil fertility technologies. Despite problems within the extension system, the absence of appropriate soils technologies to disseminate to farmers appeared to be more of a problem than the effectiveness of the extension system, although the ability to supply legume seeds for improved fallows would be necessary in the absence of considerable support from an international NGO in the Brong Ahafo region.

Improving development and dissemination of soils technologies

The research findings suggested that increasing farmer participation in the design of soil fertility management technologies could contribute to developing research outputs appropriate to farmers' circumstances in Ghana. Farmers at the forest margin are engaged in a diverse range of agricultural activities and also have differing levels of access to resources. Under these circumstances, end user participation in technology development could be effective in producing research outputs appropriate to different cropping patterns and to farmers with different sets of resource endowments (Douthwaite *et al.*, 2001; Sumberg *et al.*, 2003).

Incorporating local agro-ecological knowledge into technology development could also contribute to this process. This research demonstrated how analysis of local knowledge and comparisons between knowledge and practice could help to explain farmers' decision making behaviour, and to identify gaps in farmers' knowledge (Section 4.6). Local knowledge could therefore contribute to the identification of topics for agricultural research, and help to identify the criteria by which farmers evaluate new technologies. The knowledge based systems approach used in this research is one way of attempting to understand local agro-ecological knowledge. Using this method, intensive semi-structured interviews with a small number of farmers are used to create a knowledge base. This results in a detailed account of local knowledge about the topic of interest. During this research the distribution of the knowledge held in the knowledge bases was also tested. However this process may not always be necessary. Obtaining a detailed understanding of local knowledge through the creation of a knowledge base may frequently be sufficient for researchers to gain insights into farmers' decision making.

In addition to increasing end user involvement in technology development, decision making in agricultural research could also benefit from more information about rural livelihoods in order to be able to critically explore how research outputs are appropriate to farmers' circumstances in a broader context than the limited number of farmers participating in on-farm research. Decision making based on a more detailed understanding of rural livelihoods could target research investments at technologies applicable to large numbers of farmers, or technologies which marginalised groups such as women farmers, are able to use.

To address this issue, an integrated framework was produced to link agricultural research and rural livelihoods (Chapter 6). Within the framework information on disaggregated rural livelihoods is captured by livelihood profiles and documented within a database of livelihoods in order to make it accessible and available to decision makers involved in agricultural research and development. Researchers are required to present technologies in terms of

technology profiles which provide detailed information about the resources required for a technology to be effective, and the potential benefits of the technology for smallholder farmers.

The livelihoods database and technology profiles could be used to evaluate the potential impact of different technologies, and hence contribute to decision making about the prioritization of research and development. They could also be used to demonstrate where there is a lack of appropriate technologies available for farmers with specific resource endowments. Comprehensive information about technologies combined with information on rural livelihoods could be used to design decision support tools to help extension workers evaluate technology options for different farmers. In addition to facilitating analysis of farmers' circumstances, decision support tools could also stimulate dialogue between farmers, extension workers and researchers about the effectiveness of different technologies and their resource requirements.

A supportive institutional environment within the research and extension organisations involved would be required for information on rural livelihoods and technology requirements to contribute to decision making. The adoption of this framework would entail involvement of individuals from all levels within participating organisations in deciding what aspects of the framework to adopt and why, and how the framework would operate within the organisations.

7.1 Recommendations

Practical approaches are required to develop appropriate technologies where rural livelihoods are complex and diverse. This research has suggested a framework and a number of tools that could be used to bring together information about rural livelihoods with information about potential technologies. Formal methods for analysing livelihoods and technologies could facilitate more systematic analysis of previously neglected aspects of technology development, and could therefore lead to the development of technologies more appropriate to farmers' livelihoods.

Developing soils technologies for smallholder farmers in Ghana would benefit from increasing farmer participation in technology development, particularly during the design stage of research. Integrating legumes into cropping patterns is one way of increasing nutrient cycling, and increasing farmers' involvement in the design of improved fallow technologies could lead to production of research outputs for a greater range of cropping patterns than is currently the case, and could also produce technologies better suited to farmers' limited

resource endowments. Understanding local knowledge could contribute to the identification of relevant criteria for evaluating new technologies and the selection of topics for participatory research.

The livelihoods and agricultural activities of men have been better understood than those of women despite women's dependency on, and contribution to agricultural activities. Existing bias towards male farmers is aggravated by diversity and complexity in access to resources when attempting to understand rural livelihoods. Gender focused research should therefore be carried out to understand all aspects of the livelihoods and agricultural activities of women including those of young and married women and female household heads.

More detailed understanding of some aspects of rural livelihoods could be used to develop indicators of resource access to reduce complexity in understanding rural livelihoods, and target technology development and dissemination more effectively. More specifically, guidelines for land tenure data collection could be used to overcome apparent complexity and lack of clarity and assess differences in land scarcity. Development of methods for characterising and quantifying access to, and use of different sources of labour would help researchers to consider labour requirements in technology development.

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APPENDICES

Appendix I Checklist for Individual interviews

FARMER INFORMATION

1. Name of person being interviewed
2. Dependent/ independent in household
   If dependent – person dependent on
3. Gender
4. Indigenous/settler
   If settler place of origin
5. Approximate age
6. Highest level of education obtained
7. Any official status/position in the community
8. Main source of income
9. Other sources of income
10. Sources of information about agriculture
    Who do you go to if you have a problem on your farm?
11. Number of parcels farmed this year

INFORMATION ABOUT FARMER'S PARCELS

	Farm 1	*Farm 2*	*Farm 3*	*Etc.*
Size of parcel				
Crops grown (main crops/other crops)				
Time of year parcel cultivated: dry, major wet or minor wet season (for short duration crops only)				
Means of land acquisition and tenure arrangement If hired – cost or arrangement If sharecropped – arrangement If family land – who controls it If inherited – how - from mother, uncle etc.				
Type of land (upland/lowland, sloping/flat, soil type, forest/grassland)				
History of parcel – Is this the first year of cropping since the land was cleared? If not, what was grown there before? How long was the fallow (or was the land an old cocoa farm)? What was the vegetation on the fallow?				
Future of parcel – What will be cropped in the following year, and the year after that etc.? How many years will the land be cropped before it is fallowed again?				

12. Who makes the decisions for the farm?
13. Who is responsible for the farm?
14. Who provides the labour for the farm?
15. Inputs used
16. Crops sold
    Proportion sold and consumed
17. Livestock ownership
    Are livestock free range or stall fed?

Appendix II Farmer decision making, responsibility and labour at Subriso and Yabraso

Table II A Farm decision making, responsibility and labour reported by women at Yabraso

Id.	Origin of farmer	Household status of farmer	Control of farm plots	Responsibility for farm plots	Farm labour
2	Native	Independent	Herself	Herself	She has two young children but her husband lives elsewhere. He gives her money which she uses as she pleases. She is cultivating two plots totalling 0.6 ha with maize and cassava. She uses some of the money he gives her for clearing and weeding. She also trades in fish.
4	Native	Independent	Herself	Herself	This 58 year old widow lives with her son and a small boy. She is cultivating a 0.6 ha passed to her from her mother with a yam, groundnut, cassava rotation. She and her son provide all the labour on the farm.
16	Native	Independent	Herself	Herself	This 65 year old widow has seven children who live elsewhere and have their own farms. She is farming 4 plots of land totalling 2.2 ha on land bequeathed to her by her husband. She uses her own labour, hired labour and her children also help her on some of the parcels.
1	Settler	Dependent	Husband	Husband and herself	This settler woman works with her husband who also produces charcoal. She has no farm plot of her own. Her husband clears land, and then passes it over to the women of the household who do the planting and the weeding, although if they are unable to do it all the husband hires labour.
10	Settler	Dependent	Husband and herself	Husband and herself	This 68 year old settler woman who lives with her husband and one visiting daughter has no farm plot of her own. She works on her husband's three plots totalling 1.6 ha which he has acquired through sharecropping, a form of taungya and for free. The land was cleared with hired labour paid for by her husband. They share responsibility and decision making although she intercrops okro and pepper for herself on one parcel. Their children have also provided money which has been used for farming, and they have a cocoa plot elsewhere.
12	Settler	Dependent	Husband	Herself	This 40 year old woman farms 3 parcels of land totalling 2.0 ha, two parcels obtained from her uncle and one from her husband. Her husband makes the decisions but she is responsible for the farm, and her daughter also helps her. Her husband hired labour for clearing, and will also hire labour to help her with the weeding.
15	Native	Dependent	Herself	Herself	This 42 year old woman farms 2.2 ha of rented land in two parcels. She uses her own and hired labour, and her children also help her with the weeding. If she borrows money from her husband, she has to pay him back. She has 1.6 ha under maize and she also trades in maize.

Table II B Farm decision making, responsibility and labour reported by men at Yabraso

Id.	Origin of farmer	Household status of farmer	Control of farm plot	Responsibility for farm plot	Farm labour
3	Native	Independent	Himself	Himself	This 39 year old man farms two parcels totalling 3.0 ha on land obtained from his father-in-law. Labour is provided by himself and hired labour. His wife has no farm plot of her own, she trades and only helps him on the farm at critical times.
5	Settler	Independent	Himself	Himself	This 60 year old man farms four parcels of rented land totalling 5.3 ha. He hires labour for clearing and mounding. His wife, his children and their wives, a total of eight people, then help him on his farm.
6	Native	Independent	Himself	Himself	This 32 year old man farms 2 parcels of inherited land totalling 1.0 ha. The clearing and mounding is done by himself and contract labour. He then keeps up the farm himself without the help of any family members.
9	Native	Independent	Himself	Himself	This 20 year old man farms 2 parcels inherited from his mother. He used hired labour to clear the land and did the rest of the work himself. His wife decides with him when to harvest.
11	Native	Independent	Himself	Himself	This 57 year old man farms 2 parcels of land totalling about 1.2 ha. He provides all the labour on his farm. He has no wife.
13	Settler	Independent	Himself	Himself	This 36 year old school teacher farms on a part time basis. He has 2 parcels of rented land totalling 1.2 ha. He used his own and hired labour to clear the land.
14	Settler	Independent	Himself	Himself	This 25 year old man farms 3 parcels of hired land totalling 2.4 ha. He used his own and hired labour to clear the land. His wife provides food and water for him on the farm and sows the groundnuts but does not help with weeding.

Table II C Farm decision making, responsibility and labour reported by women at Subriso

Id.	Origin of farmer	Household status of farmer	Control of farm plot	Responsibility for farm plot	Farm labour
9	Settler	Independent	Herself	Herself	This 60 year old woman cultivates 2 plots totalling 0.8 ha. on inherited land. She uses hired labour for clearing, mounding and weeding. However her husband and children also help with the farm. Her husband lives in Techiman.
10	Native	Independent	Herself	Herself	This 30 year old woman whose husband is in Libya cultivates 4 plots totalling more than 1.6 ha. She does the clearing and weeding with her children but hires labour for mounding and ridging. She also does petty trading.
21	Native	Independent	Herself	Herself	This 56 year old woman cultivates 5 plots totalling over 4.0 ha. She hired labour paid for by herself for clearing, mounding, ridging and weeding. She is also helped on the farm by her children.
5	Settler	Dependent	Her husband	Herself	This 40 year old woman cultivates 5 plots totalling 3.4 ha, of which 1.6 ha are maize, on a sharecropping basis. She hired labour to clear the plots and mound. The rest of the farm work is done by herself and her children. Her husband has his own farm. He also distils akpeteshie and owns a corn mill.
2	Settler	Dependent	Herself	Herself	This 30 year old woman came to Subriso less than a year ago with her husband. She cultivates 1 sharecropped parcel of 0.8 ha together with her husband. Her husband cleared the land, and the weeding is done by herself, her husband and children. She sometimes hires out her own labour on other people's farms.
4	Settler	Dependent	Herself	Herself	This 50 year old woman cultivates 4 plots totalling 2.0 ha ac. on rented, sharecropped and land given at no cost. She has 1 mixed plot and 3 sole maize parcels. She uses some hired labour for clearing and weeding. She pays for this herself, although her children also give her money which she uses. She also does some trading.
12	Native	Dependent	Herself	Herself	This 43 year old woman cultivates 4 plots of inherited land of over 4.0 ha. She uses money from her husband to hire labour on her farm. She is also helped by her husband, her brother and her children. Her husband and brother have their own parcels also.
14	Native	Dependent	Herself	Herself	This 32 year old woman cultivates 5 plots totalling 2.0 ha. 4 of the plots are inherited and 1 is rented for tomatoes. She sells most of the produce. She cleared the parcels with the help of hired labour for which she paid herself, and also uses hired labour to maintain the parcels.
22	Native	Dependent	Herself and her husband	Her husband	This 31 year old woman cultivates 6 plots totalling about 2.8 ha. together with her husband. They obtained the land from her father. Mounding was done by herself and her husband. Weeding is done by herself and hired labour for which her husband pays. She also does some petty trading.
35	Settler	Dependent	?	?	This 35 year old woman has 0.4 ha of a maize/cassava intercrop. She hired labour to clear the land and weeded the plot with the help of her friends. She does not receive any help on the farm from her husband, although she helps him on his parcels. The money she gets from her farm is given to her husband.
36	Native	Dependent	?	?	This 35 year old woman works together with her husband and children on 4 plots totalling over 2.0 ha which is land obtained from her mother. The land was cleared and planted by her husband. Hired labour was used for weeding. She also sells cooked food.

Table II D Farm decision making, responsibility and labour reported by men at Subriso

Id.	Origin of farmer	Household status of farmer	Control of farm plot	Responsibility for farm plot	Farm labour
1	Settler	Independent	Himself and his landlord	Himself and his family	This 70 year old man cultivates 3 plots totalling 1.6 ha on a sharecropping basis. His landlord specifies what crops can be grown. Work on the farm is done by himself and his family, he sometimes uses hired labour
3	Settler	Independent	Himself	Himself	This 25 year old man cultivates 0.4 ha of sole maize. He works on the farm himself, and is also helped by *nnoboa* and by 3 women (who also have their own parcels). He does not hire labour on his farm. He also hires out his own labour.
6	Settler	Independent	Himself	Himself	This 32 year old man cultivates 2 plots totalling 3.8 ha, the majority of which is maize, on rented and sharecropped land. The land was cleared by himself and hired labour, and weeding was done by himself and *nnoboa*. His 2 wives also help him, although they also have their own farms.
7	Settler	Independent	Himself		This 62 year old man cultivates 3 plots totalling 4.2 ha, 2 plots on a sharecropping basis and 1 given him for free. 6 ac. is sole maize. He makes the decisions with his wife although he controls what is done. He works on the farm with his wife and 2 adult daughters. He used hired labour to clear the land. His wife has no farm plot of her own. He is also the caretaker of a cocoa plot and his wife processes palm oil.
8	Native	Independent	Himself	Himself	This 18 year old man cultivates 4 plots totalling 1.6 ha that he obtained from his family, through sharecropping and renting. He has no wife and works on the farm mainly with his sister. He did the clearing and mounding himself, and does the weeding with his sister.
17	Settler	Independent	Himself	Himself	This 48 year old man cultivates 4 plots totalling over 2.8 ha of sharecropped and rented land. His wife provides labour on the farm and has no plots of her own. He is also the caretaker of a cocoa plot and hires out his own labour. His wife sells *kenkey*, soup and processes palm oil when they have money.
18	Settler	Independent	Himself	Himself	This 58 year old man cultivates 2 plots totalling 1.6 ha on land that has been given to him to crop for free. He uses his own labour. He has no wife.
19	Native	Independent	Himself and his wife	Himself	This 30 year old man cultivates 5 plots totalling 2.1 ha on land obtained from his wife's father, his brother and a friend, and 10 ac. of his brother's oil palm. He did the clearing and mounding himself. He will turn his maize and groundnut parcels over to his wife for upkeep and weeding. He also paints signs and his wife plaits hair.
20	Native	Independent	Himself and his wife	Himself and his wife	This 38 year old man cultivates 7 plots totalling over 4.5 ha of family land. He does the clearing and weeding with the help of hired labour, and also uses hired labour for mounding and ridging. He turned his groundnut plot over to his wife for upkeep. He also owns a corn mill.
23	Settler	Independent	Himself	Himself	This 30 year old man cultivates 4 plots totalling 1.1 ha obtained by renting, from his father and for free. He works on his parcels together with hired labour. His wife helps with weeding, particularly on his pepper and plantain parcels. He also repairs bicycles.
24	Native	Independent	Himself	Himself	This 40 year old man cultivates 4 plots of rented, sharecropped and family land. His wife has her own parcels. He also hires out his own labour.

Appenix III Questionnaire used to test knowledge distribution

Recorder..... Village.....
Date..... District.....
Region.....

Name of interviewee.....
Gender: Male..... Female..... Ethnicity.....
Age..... Number of years in village.....

School leaving class:
None ..... Middle school.....
Primary ..... SSS.....
JSS..... Tertiary.....
Other (specify).....

Farming as occupation: major..... minor.....
Other income generating activities/ employment.....

3 most important crops grown for cash (rank):

Cocoa....	Plantain.....	Tomatoes....	Other.....
Oil palm....	Cassava....	Garden egg....	.....
Citrus.....	Cocoyam....	Okro....	
Rubber.....	Yam.....	Pepper....	
Maize.....	Rice....	Green pepper....	
Groundnut....	Sugar cane....	Cabbage...	
Cowpea....	Taro....		

4 most important crops grown for home consumption:

Plantain....	Maize....
Cassava....	Groundnut....
Cocoyam....	Cowpea....
Yam....	Vegetables....
	Other.....

Means of access to land for farming:

Individual land (individual has sole rights over land)..... Sharecropped land.....
Family land..... Rented land.....
Spouse's land..... Unused building plot.....
Other.....

Gender of household head: Male..... Female.....
Relationship to household head: Self..... Spouse.... Parent..... Uncle..... Other.....

Marital status
Married.....
Married but living in a separate town from spouse.....
Single.....
Divorced.....
Widowed.....

Number of children.....
Age range of children: Youngest..... Oldest.....

How many times a year does the farmer speak to an extension agent (if farmer says visits are very irregular ask how many times in the last year)?
Never..... 6 – 10 times.....
1 – 2 times..... More than 10 time.....
3 – 5 times.....

A Weeds

1) Name some (maximum of 5) weeds that are the most troublesome on your farms?

a. .....
b. .....
c. .....
d. .....
e. .....

Is the weed acheampong/ topiah (*Chromolaena odorata*) difficult or easy to control?

Difficult..... Easy.....

2) Why?

Tick facts in answer

- ☐ difficult because it grows fast
- ☐ difficult because it produces a lot of seed
- ☐ difficult because the germination of the seed is very rapid
- ☐ difficult because it regrows rapidly when slashed
- ☐ it is difficult to uproot
- ☐ easy because it is not necessary to uproot it before planting crops such as plantain or cassava

Other:

3) Is acheampong / topiah (*Chromolaena odorata*) a good plant or a bad one to have on your land?

Good..... Bad.....

4) Why?

Tick facts in answer

- ☐ It shades out *Panicum maximum* (esre / ageabosu)
- ☐ It shades out other weeds
- ☐ It smothers the growth of trees
- ☐ The soil under acheampong is moist
- ☐ The soil under acheampong is fertile or rich in organic matter
- ☐ It is not as troublesome as other weeds

Other:

5) Which of the following weeds are fairly easy to uproot and which are difficult?

	Weed	Difficult	Easy	Don't know
A	Hwedee / nantwri sre (*Pennisetum purpureum*/ Elephant grass)			
B	Esre / wageabosu (*Panicum maximum*/ Guinea grass)			
C	Adanko milk (*Euphorbia heterophylla*)			
D	Brantwuata/ tweta (*Sida acuta*)			

6) Which of the following weeds grow fast, and which grow slowly?

	Weed	Fast	Slowly	Don't know
A	Acheampong/ topiah (*Chromolaena odorata*)			
B	Rawlings (*Cenchrus ciliaris*)			
C	Nyamenemewu (*Commelina vulgare*)			

7) Which of the following weeds regrow after slashing them with a cutlass?

	Weed	Regrows	Doesn't regrow	Don't know
A	Acheampong/ topiah (*Chromolaena odorata*)			
B	Esre / wageabosu (*Panicum maximum*/ Guinea grass)			
C	Nkyenkyema (*Rottboellia exaltata*)			

8) Which of the following weeds are able to produce roots from nodes on the stem?

	Weed	Produces roots	Doesn't produce roots	Don't know
A	Asaase ne abuo (*Portulaca spp.*)			
B	Acheampong/ topiah (*Chromolaena odorata*)			
C	Nyamenemewu (*Commelina vulgare*)			

9) Which of the following weeds are deep rooted and which have relatively shallow roots?

	Weed	Deep	Shallow	Don't know
A	Brantwuata/ tweta (*Sida acuta*)			
B	Rawlings (*Cenchrus ciliaris*)			
C	Ananse treumohoma/ amantum wire (*Centrosema spp.*)			
D	Eton (*Imperata cylindrica*/ spear grass)			

10) Which of the following weeds is able to tolerate moisture stress (especially in the dry season)?

	Weed	Drought tolerant	Not drought tolerant	Don't know
A	Brantwuata/ tweta (*Sida acuta*)			
B	Asaase ne abuo (*Portulaca spp.*)			
C	Anomanunsan			

11) Which of the following weeds produces a lot of seeds?

	Weed	Many seeds	Few seeds	Don't know
A	Adanko milk (*Euphorbia heterophylla*)			
B	Nkyenkyema (*Rottboellia exaltata*)			
C	Awaha			
D	Mmetrie (*Cyperus rotundus* / nut grass)			

12) How are the seeds of the following weeds dispersed?

	Weed	Means of seed dispersal	Don't know
A	Acheampong/ topiah (*Chromolaena odorata*)		
B	Bosumwuajura/ bokoboko (*Talinum triangulare*)		
C	Awaha		
D	Mmetrie (*Cyperus rotundus* / nut grass)		
E	Ananse treumohoma/ amantum wire (*Centrosema spp.*)		

13) What different ways are weed seeds dispersed?

Tick facts in answer

- ☐ by the wind
- ☐ by timber machinery
- ☐ by birds
- ☐ by mammals
- ☐ on people's shoes and clothing
- ☐ by the river

Other:

14) Which of the following do you agree with:

A reduction in the number of trees causes an *increase in the dispersal of weeds* by the wind.
A reduction in the number of trees *does not change the dispersal of weeds* by the wind.
A reduction in the number of trees causes a *decrease in the dispersal of weeds* by the wind.

a. Don't know

15) Why, after weeding under crops do farmers often use the slashed weeds to mulch the farm?

Tick facts in answer

- ☐ Prevents further weed regrowth
- ☐ Adds organic matter to the soil
- ☐ Prevents germination of weed seeds in the soil
- ☐ Prevents the evaporation of moisture from the surface of the soil
- ☐ Adds organic matter to the soil when the weeds decompose
- ☐ Prevents the sun from heating up the soil
- ☐ Prevents the soil from becoming hard
- ☐ Prevents surface runoff and soil loss through soil erosion

Other:

16) Why, after weeding under crops do farmers place the slashed weeds in a heap?

Tick facts in answer

- ☐ To prevent the resprouting of the weeds from roots and other vegetative material.
- ☐ To make it easier to move around the farm

Other

17) How does soil fertility influence the growth of weeds?

Tick facts in answer

- ☐ low soil fertility causes an increase in the growth of weeds on farm

Other:

18) How does light influence the growth of weeds?

Tick facts in answer

- ☐ light promotes the growth of weeds or shading/ lack of light suppresses weed growth
- ☐ light promotes the germination of weed seeds

Other:

19) How can you reduce the amount of light available to weeds?

Tick facts in answer

- ☐ Planting crops at close spacing so that canopy formation is rapid
- ☐ Planting a cover crop such as mucuna
- ☐ Intercropping so that there is a always some canopy to suppress weed growth
- ☐ Mulching the farm with slashed weeds

Other:

20) How can you reduce the amount of weed seeds in your farm?

Tick facts in answer

- ☐ Burning the farm destroys weed seeds.
- ☐ Weeding the farm before the weeds on it have a chance to flower and produce seed.
- ☐ Fallowing the farm

Other:

21) At what stage is it most effective to clear weeds from the farm so that they don't compete with crops and don't regrow?

Tick facts in answer

- ☐ At the two or three leaf stage i.e. very young
- ☐ Before setting seed

Other:

22) What sort of things distinguish a nwura bone from other weeds?

Tick facts in answer

- ☐ Rapid growth
- ☐ Sprouting from underground parts such as roots, rhizomes, etc.
- ☐ Presence of irritating parts such as spines or irritant hairs
- ☐ Weeds that due to their growth habit must be picked by hand e.g. Centrosema which climbs up maize stalks and brings them down
- ☐ Difficult to uproot
- ☐ Rapid completion of reproductive cycle
- ☐ Prolific seed production
- ☐ Weeds that are not controlled by burning

Other:

23) Do you know the names of any herbicides?
   a. Yes..... No.....
   b. If yes, give the names:

Tick names given by farmers:

- ☐ Roundup
- ☐ Gramoxone
- ☐ atrazine
- ☐ Calliherbe

Other

24) Which of the following do you agree with:

   a. Roundup kills all weeds – both grasses and broadleafs
   b. Roundup kills only broadleaf weeds
   c. Roundup kills only grasses
   d. Don't know (go to question 27)

25) What factors influence the effectiveness of Roundup

Tick facts in the answer

- ☐ Rainfall within 4 hours of application reduces effectiveness
- ☐ The strength of the herbicide solution i.e. the amount of Roundup used
- ☐ Roundup is most effective when weeds are 5 – 30cm tall
- ☐ The type of weed

Other:

26) Which of the following do you agree with:

   a. Gramoxone kills all weeds – both grasses and broadleafs
   b. Gramoxone kills only broadleaf weeds
   c. Gramoxone kills only grasses
   d. Don't know

27) Have you ever used a herbicide? Yes..... No.....

B Soil fertility

28) How is the black layer (organic matter) formed on the surface of the soil?

Tick facts in answer

□ The decomposition of vegetation (plant parts)

Other

29) What things decompose and form the black layer on the surface of the soil?

Tick facts in answer

□ leaves and other vegetation
□ animal manure
□ black soil from the rubbish heap
□ old cassava and plantain peelings
Other

30) What is the soil of the black layer like?

Tick facts in answer

□ it is soft (emire)
□ water infiltrates well, there is little surface runoff
□ water is retained well, the soil does not dry out quickly
□ it provides plant food
□ you find earthworms in it
□ it makes the soil cool (enyunu)
□ the soil is matured
□ crops do well on it/ give a high yield
Other

31) What are your two most important crops?
   a. Crop 1..... Crop 2.....
   b. Describe suitable land or soil for cultivating Crop 1

   c. Describe suitable land or soil for cultivating Crop 2

32) Which of the following do you agree with:
   a. After land has been left to fallow for ten years there are *more pests and diseases* in the soil
   b. After land has been left to fallow for ten years there are *the same amount of pests and diseases* in the soil
   c. After land has been left to fallow for ten years there are *less pests and diseases* in the soil
   d. Don't know

33) Which of the following do you agree with:
   a. After land has been left to fallow for ten years there are *more weed seeds* in the soil
   b. After land has been left to fallow for ten years there are *the same amount of weed seeds* in the soil
   c. After land has been left to fallow for ten years there are *fewer weed seeds* in the soil
   d. Don't know

34) Which of the following do you agree with:
   a. After land has been left to fallow for ten years there are *more earthworms* in the soil
   b. After land has been left to fallow for ten years there are *the same amount of earthworms* in the soil
   c. After land has been left to fallow for ten years there are *fewer earthworms* in the soil
   d. Don't know

35) What crops would do well on the following types of land?

	Suitability (yes/ no/ don't know)	Cocoa	Plantain	Oil palm	Maize	Vegetables	Yam	Other
Land with a thick covering of Panicum maximum (esre/ ageaboso)	Suitable.... Unsuitable.... Don't know....							
Land left fallow for 4 – 5 years that is now covered with mature Chromolaena odorata (acheampong/ topiah) plants and a few small trees	Suitable.... Unsuitable.... Don't know....							
Land that has been left fallow for 2 – 3 years and has a dense covering of Chromolaena odorata with many stems	Suitable.... Unsuitable.... Don't know....							
Land with a thick covering of Pennisetum purpureum (hwedee/ nantwri sre)	Suitable.... Unsuitable.... Don't know....							
Land with some trees, sparse undergrowth and some large creepers and vines (nfofo kwae)	Suitable.... Unsuitable.... Don't know....							
Land with a thick covering of Cenchrus ciliaris (rawlings)	Suitable.... Unsuitable.... Don't know....							
Land with a thick covering of dark green Rottboellia exaltata (nkyenkyema)	Suitable.... Unsuitable.... Don't know....							

36) How does burning the cleared vegetation after the fallow influence the soil and its cultivation?

Tick facts in answer

- ☐ it makes it easier to work on the land
- ☐ there are fewer weeds
- ☐ it destroys weed seeds
- ☐ it makes the soil friable so that water infiltrates well
- ☐ it creates ash which acts as fertiliser
- ☐ it destroys plant pests and diseases in the soil
- ☐ it enhances the sprouting of cocoyam

Other

37) Do you think it is good or bad for the sun to be shining on bare soil on the farm?

a. It doesn't matter (*go to Inorganic fertiliser*) ..... It's bad..... Don't know..... (*go to Inorganic fertiliser*)

b. If its bad, then why?

Tick facts in answer

- ☐ it makes the soil hot
- ☐ it makes the soil hard
- ☐ it dries the soil out
- ☐ it causes the soil to crack

Other

c. What ways do you know of protecting the soil from the sun?

Tick facts in answer

- ☐ mulching with slashed weeds
- ☐ retaining trees and shrubs on farm
- ☐ cultivation of Mucuna
- ☐ cultivation of sweet potato
- ☐ mixed cropping with plantain, cocoyam which provides crop canopy cover

Other

Inorganic fertiliser

38) What effect does inorganic fertiliser have on crops?

Tick facts in answer

- ☐ increases yield (size or quantity of harvested product)
- ☐ increases crop growth rate
- ☐ increases vegetative growth of crop
- ☐ Don't know

Other

39) What effect does inorganic fertiliser have on the soil?

Tick facts in answer

- ☐ it makes the soil fertile
- ☐ it makes the soil cool
- ☐ it makes a lot of weeds grow

Other

40) Which of the following do you agree with:
   a. Using inorganic fertiliser to grow tomatoes causes the tomatoes to be *more palatable*.
   b. Using inorganic fertiliser to grow tomatoes *does not change the palatability* of the fruit.
   c. Using inorganic fertiliser to grow tomatoes causes the tomatoes to be *less palatable*.
   d. Don't know

41) Which of the following do you agree with:
   a. Using inorganic fertiliser to grow tomatoes causes the tomatoes to have a *longer shelf life*.
   b. Using inorganic fertiliser to grow tomatoes *does not change the shelf life* of the tomatoes.
   c. Using inorganic fertiliser to grow tomatoes causes the tomatoes to have a *shorter shelf life*.
   d. Don't know

42) Which of the following do you agree with:
   a. Using inorganic fertiliser to grow cassava *increases the quality* of the cassava for making fufu.
   b. Using inorganic fertiliser to grow cassava *does not change the quality* of the cassava for making fufu.
   c. Using inorganic fertiliser to grow cassava *decreases the quality* of the cassava for making fufu.
   d. Don't know

43) Which of the following do you agree with:
   a. Using inorganic fertiliser on plantain *increases black ant and termite attack.*
   b. Using inorganic fertiliser on plantain *does not change black ant and termite attack.*
   c. Using inorganic fertiliser on plantain *reduces black ant and termite attack.*
   d. Don't know

44) Have you heard of the following types of fertiliser?

Tick types which farmers have heard of:

- ☐ 15: 15: 15
- ☐ 23: 15: 5
- ☐ 20: 20: 0
- ☐ Other compound fertilisers
- ☐ Ammonia (ammonium sulphate)
- ☐ Urea

Others not listed

.....

45) What is the difference between compound fertiliser (such as 15:15:15) and ammonia? (particularly with regard to crop growth)

Tick facts in answer

- ☐ Compound fertiliser is for vegetative growth
- ☐ Compound fertiliser produces large fruits
- ☐ Ammonia is for fruiting and flowering
- ☐ Ammonia dissolves very quickly whereas compound fertiliser takes longer to dissolve
- ☐ Ammonia is used only in the dry season
- ☐ Ammonia makes the leaves of plants very green
- ☐ Don't know

Other

46) What happens if you apply too much ammonia?

Tick facts in answer

- ☐ Too much ammonia makes vegetable fruits (such as tomato) rot quickly
- ☐ Too much ammonia causes excessive vegetative growth
- ☐ Too much ammonia scorches crops
- ☐ Don't know

Other

47) Can 15: 15 or ammonia or any other type of fertiliser scorch crops?

a. Yes..... No..... (go to question 49)

b. If yes then how?

Tick facts in answer

- ☐ It scorches crops if it is placed too close to them or touches them
- ☐ It scorches crops if it is applied when the soil is dry
- ☐ It scorches crops if you apply too much
- ☐ Don't know

Other

48) Describe how you would fertilise either a crop of maize or a crop of vegetables, or another crop. (If farmer is unable to describe then tick here..... and move to question 50)

a) Specify name of crop.....

b)How many times would you apply fertiliser? .....

c) When would you apply it to the crop? What type would you use? How much would you use?

	Time of application	Type of fertiliser	Solution or dry form	If solution, describe preparation (amount water/ amount fertiliser	Quantity (per plant)	Any other conditions
Application 1						
Application 2						
Application 3						
Application 4						
Application 5						
Application 6						

49) Do you know of any foliar fertilisers? Yes..... No..... If yes can you name them and say what they do?

Tick names given

Name		*Description – what does it do?*
☐	Agua	.....
☐	Sampe	.....
☐	Plant Food (phostrogen)	.....
Other.....		.....

50) Can fertiliser be bad for the soil?

a. Yes..... No ..... Don't know.....
b. If yes, then how?

51) Have you ever used inorganic fertiliser? Yes..... No.....

C Manure

52) Can animal manure be used as a type of fertiliser?
a) Yes..... No.....
b) If yes, which animals' manure can be used?

Tick facts in answer

- ☐ Goat or sheep manure
- ☐ Cattle manure
- ☐ Pig manure
- ☐ Poultry manure
- ☐ Other (specify).....
- ☐ Any

53) What effect does animal manure have on the soil?

Tick facts in answer

- ☐ it is a source of plant food
- ☐ it improves the water storage capacity of the soil
- ☐ it improves soil texture
- ☐ it makes the soil easier to dig
- ☐ it is a source of organic matter
- ☐ it makes crops grow faster
- ☐ it increases the yield of crops
- ☐ Other (specify).....

54) Which of the following do you agree with:
a. Using poultry manure on crops *increases the palatability* of vegetables.
b. Using poultry manure on crops *does not change the palatability* of vegetables.
c. Using poultry manure on crops *reduces the palatability* of vegetables.
d. Don't know

55) Which of the following do you agree with:
   a. Using poultry manure *increases the amount of weeds* on farm
   b. Using poultry manure *does not change the amount of weeds* on farm
   c. Using poultry manure *reduces the amount of weeds* on farm
   d. Don't know

56) Can animal manure scorch crops?
   a. Yes..... No.....
   b. If yes, then how?

Tick facts in answer

- ☐ if it is not properly decomposed
- ☐ if it is placed too close to the plant or touches it
- ☐ if there is no moisture in the soil

Other

57) Can fresh animal manure be used on crops?

   a. Yes..... [proceed to question 59] No..... Don't know..... [proceed to question 59]
   b. If no, how do you ensure speedy decompostion of animal manure?

Tick facts in answer

- ☐ Heaping it
- ☐ Keeping manure moist
- ☐ Turning the manure
- ☐ Mixing it with sawdust
- ☐ Don't know

Other

   c. How is it possible to tell when animal manure is well decomposed and ready for use in the field?

Tick facts in answer

- ☐ the temperature: the manure is not hot, even at the centre of the heap
- ☐ appearance: the manure looks and feels like soil
- ☐ the smell: no strong smell of ammonia
- ☐ Don't know

Other

58) Have you ever used animal manure? Yes..... No.....

D Cover crops

59) Do you know of any cover crops? Yes..... No..... If yes, then name them.

Tick names farmers give

- ☐ Sweet potato
- ☐ Efre
- ☐ Cowpea
- ☐ Pueraria
- ☐ Mucuna (adua apea)
- ☐ Canavalia
- ☐ Centrosema

Other

60) Have you ever heard of the following?

Tick cover crops farmers have heard of.

Pueraria	Yes.....	No.....
Mucuna (adua apea)	Yes.....	No.....
Canavalia	Yes.....	No.....
Centrosema	Yes.....	No.....

61) What are the benefits of growing a cover crop?

Tick facts in answer

- ☐ reduces soil erosion
- ☐ increases soil organic matter
- ☐ provides plant food to subsequent crops
- ☐ reduces the number of weeds on the field in the subsequent cropping season
- ☐ conserves soil moisture
- ☐ fixes nitrogen
- ☐ reduces soil borne nematodes
- ☐ Don't know

Other

62) Describe the use of one cover crop. (Tick here if farmer is unable to respond ..... and go to next question)

a. Name of cover crop.....

b. Is it grown in association with other crops? If yes, which crops? Yes... Crops..... No...

c. What are its benefits?

Tick facts in answer

- ☐ provides a human food stuff
- ☐ prevents the growth of other weeds
- ☐ reduces the number of weeds on the field in the subsequent cropping season
- ☐ increases soil organic matter
- ☐ provides plant food to subsequent crops
- ☐ conserves soil moisture
- ☐ fixes nitrogen
- ☐ Don't know

Other

d. Describe how it is cultivated (if it is intercropped with other crops find out when and how).

63) Have you ever grown a cover crop? Yes..... No.....

Appendix IV Characteristics of farmers from the knowledge generalisation survey

Table IV A Farmer location and gender

Gender	Number of farmers in each block					
	Wenchi	Sunyani	Kumasi	Obuasi	Asankrangua	Total
Male	20	22	23	21	21	107
Female	22	20	19	21	21	103
Total	42	42	42	42	42	210

Table IV B Residency status of farmers

Years resident in current village	Proportion of farmers (%)					
	Wenchi	Sunyani	Kumasi	Obuasi	Asankrangua	Total
Since birth	45	30	59	66	55	51
>20	24	20	7	17	17	17
11-20	14	23	10	10	14	14
6-10	10	10	17	2	10	10
1-5	7	18	7	5	5	8
Total	100	100	100	100	100	100

Table IV C Farmer origin

Ethnic origin	Number of farmers (%)					
	Wenchi	Sunyani	Kumasi	Obuasi	Asankrangua	Total
Southern*	90	57	100	98	93	88
Northern+	10	43	0	2	7	22
Total	100	100	100	100	100	100

*From the southern regions of Ghana i.e. Greater Accra, Central, Ashanti, Eastern, Volta and Brong Ahafo. +From Northern regions of Ghana i.e. Northern, Upper East and Upper West regions, and other West African countries.

Table IV D Farmer age

Age range	Number of farmers (%)
< 31	27
31 - 40	30
41 - 50	20
51 - 60	12
> 60	11

Table IV E Education of farmers by age

Last school attended	Number of farmers (%)					
	Age range					Total
	< 31	31 - 40	41 - 50	51 - 60	> 60	
None	13	18	33	60	54	29
Primary	11	13	23	12	17	15
Junior Secondary School (JSS) or Middle School	61	56	40	24	25	47
Higher than JSS or Middle School	16	13	5	4	4	10
Total	100	100	100	100	100	100

Table IV F Education of farmers by gender

Last school attended	Number of farmers (%)	
	Male	Female
None	20	38
Primary	11	18
Junior Secondary School (JSS) or Middle School	50	43
Higher than JSS or Middle School	19	1
Total	100	100

Table IV G Cultivation of cash crops amongst male and female farmers

Crop	Number of farmers (%)	
	Male	Female
Cassava	59	83
Maize	66	46
Plantain	36	61
Cocoa	36	24
Yam	22	20
Vegetable	21	16
Cocoyam	12	24
Groundnut	9	11
Oil palm	13	5
Rice	3	1
Citrus	3	0
Cowpea	3	0
Other	6	2
Total	100	100

Table IV H Farmers with and without non-farm income generating activities

Possession of a non-farm income generating activity	Number of farmers (%)					
	Wenchi	Sunyani	Kumasi	Obuasi	Asankrangua	Total
Yes	62	33	57	43	38	47
No	38	67	43	57	62	53
Total	100	100	100	100	100	100

Appendix V Results of laboratory soils analyses

Table V I Analysis of soils from Johnsonkrom

Soil type			Available N (mg kg^{-1})			P (mg kg^{-1})			K (mg kg^{-1})			pH			EC (µS cm^{-1})		
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.
Stony soil	*Abontem*	t	22.0	50.7	16.42	2.5	1.3	0.37	114.5	116.8	34.85	5.87	1.24	0.36	129	193	58.20
Sandy soil	*Anwea*	t	12.5	5.2	1.52	3.1	2.7	0.82	53.2	10.7	3.54	6.80	0.06	0.02	65	29	9.21
Red soil	*Asase kokoo*	t	15.9	4.2	1.29	4.0	2.1	0.60	199.0	155.6	48.86	7.03	0.21	0.07	176	56	16.74
Black soil	*Asase tuntum*	t	11.0	5.8	1.87	2.3	1.3	0.44	26.3	40.5	13.51	6.36	1.65	0.50	73	20	6.51

Table V J Analysis of soils from Johnsonkrom

Soil type			gravel (%)			Organic matter (%)			Water holding capacity (%)			Texture
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	
Stony soil	*Abontem*	t	22.0	38.0	11.01	6.4	2.6	0.81	36.8	10.0	2.99	sandy loam
Sandy soil	*Anwea*	t	0.0	0.0	0.00	2.5	0.6	0.19	33.6	0.6	0.19	loamy sand
Red soil	*Asase kokoo*	t	8.6	20.0	5.96	9.8	2.1	0.61	46.6	9.2	2.94	silt loam with grit
Black soil	*Asase tuntum*	t	0.0	0.0	0.00	4.6	1.7	0.50	46.8	9.7	2.84	sandy loam

Table V K Analysis of soils from Monta

Soil type			Available N (mg kg^{-1})			P (mg kg^{-1})			K (mg kg^{-1})			pH			EC (µS cm^{-1})		
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.
Sandy soil (black)	*Afonwea tuntum*	s	17.8	14.7	4.25	8.7	14.0	4.63	333.9	490.4	141.95	7.25	1.08	0.33	143	137	43.25
Sandy soil (black)	*Afonwea tuntum*	t	14.1	8.4	2.57	70.7	151.0	7.78	618.5	467.7	138.24	7.84	0.68	0.21	267	401	130.93
Red soil	*Asase kokoo*	s	21.7	26.4	8.04	2.7	1.7	0.57	117.4	72.0	23.44	6.28	0.41	0.12	151	50	15.39
Red soil	*Asase kokoo*	t	35.7	11.3	3.62	7.2	4.8	1.51	468.9	362.3	117.07	6.96	0.56	0.17	238	31	9.39
Clay soil	*Ateche*	s	15.2	24.8	7.46	18.1	18.7	5.41	110.4	28.3	8.18	6.08	0.50	0.17	110	97	28.04
Clay soil	*Ateche*	t	6.0	2.9	0.85	36.3	43.3	12.69	182.8	335.6	102.25	6.42	1.33	0.43	148	148	47.03

Table V L Analysis of soils from Monta

Soil type			gravel (%)			Organic matter (%)			Water holding capacity (%)			Texture
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	
Sandy soil (black)	*Afonwea tuntum*	s	0.5	1.2	0.38	2.6	1.5	0.44	32.7	8.8	2.55	sandy loam
Sandy soil (black)	*Afonwea tuntum*	t	0.2	0.1	0.03	4.7	2.3	0.68	43.2	9.2	2.69	sandy loam
Red soil	*Asase kokoo*	s	8.2	20.8	6.40	9.4	4.4	1.29	50.1	18.0	5.46	sandy to clay loam
Red soil	*Asase kokoo*	t	1.9	5.3	1.73	11.9	1.4	0.42	58.2	4.4	1.28	clay loam
Clay soil	*Ateche*	s	0.0	0.0	0.00	6.6	3.4	1.01	61.5	19.8	5.93	clay loam
Clay soil	*Ateche*	t	0.0	0.0	0.00	8.4	1.5	0.49	67.2	16.4	4.84	silt to clay loam

Table V M Soils analysis from Sereso

Soil type			Available N (mg kg^{-1})			P (mg kg^{-1})			K (mg kg^{-1})			pH			EC (µS cm^{-1})		
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.
Stony soil	*Abusea*	s	3.0	2.8	0.83	2.1	0.3	0.08	19.7	7.7	2.35	6.71	0.71	0.21	45	55	16.41
Stony soil	*Abusea*	t	6.8	10.9	3.16	3.4	1.8	0.54	125.2	173.2	50.01	7.11	0.25	0.07	70	56	16.29
Sandy soil	*Anwea*	s	4.6	2.5	0.84	2.9	0.4	0.12	58.3	153.6	48.85	6.68	0.38	0.11	31	20	5.78
Sandy soil	*Anwea*	t	29.8	33.2	9.62	5.2	6.1	1.91	199.7	434.2	136.37	6.30	0.72	0.24	104	87	26.41
Clay (white) soil	*Asase fufuo*	s	3.2	2.6	0.76	9.2	8.4	2.57	90.9	162.0	46.94	7.39	1.88	0.56	65	28	8.09
Clay (white) soil	*Asase fufuo*	t	10.7	7.9	2.35	17.7	19.2	5.78	159.5	74.6	24.02	8.03	0.34	0.10	136	71	22.73
Red soil	*Asase kokoo*	s	3.8	3.0	0.88	2.4	1.2	0.36	18.5	29.2	8.87	7.29	1.56	0.47	47	44	13.42
Red soil	*Asase kokoo*	t	12.2	6.0	1.75	4.0	4.4	1.43	158.6	91.9	27.63	7.25	1.01	0.31	100	36	11.84
Black soil	*Asase tuntum*	s	3.3	1.1	0.34	5.9	11.3	3.59	33.4	43.7	12.79	7.91	1.09	0.35	76	60	17.35
Black soil	*Asase tuntum*	t	13.1	3.2	0.93	13.4	15.0	4.46	188.4	267.7	80.87	7.81	0.68	0.22	123	39	12.68

Table V N Analysis of soils from Sereso

Soil type			gravel (%)			Organic matter (%)			Water holding capacity (%)			Texture
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	
Stony soil	Abusea	s	33.6	35.9	10.52	5.2	2.8	0.82	34.2	24.9	7.33	clay loam with grit
Stony soil	Abusea	t	16.8	43.5	14.45	8.1	5.1	1.60	43.2	21.8	7.08	sandy to clay loam with grit
Sandy soil	*Anwea*	s	2.6	7.7	2.57	1.8	0.7	0.20	25.3	10.5	3.03	sandy loam
Sandy soil	*Anwea*	t	0.1	0.2	0.06	4.4	3.1	0.89	41.3	21.9	6.37	sandy loam
Clay (white) soil	*Asase fufuo*	s	0.3	0.8	0.25	4.5	0.5	0.14	46.2	0.2	0.04	clay loam
Clay (white) soil	*Asase fufuo*	t	0.1	0.4	0.14	7.0	3.2	0.95	54.3	15.9	4.67	silty loam
Red soil	*Asase kokoo*	s	23.7	27.4	8.95	4.5	0.2	0.05	35.9	13.2	4.15	silty to clay loam with grit
Red soil	*Asase kokoo*	t	3.0	9.1	3.02	7.6	2.2	0.69	49.9	10.4	3.08	silt loam
Black soil	*Asase tuntum*	s	7.7	22.9	7.62	3.6	2.0	0.58	39.5	17.7	5.14	silt loam
Black soil	*Asase tuntum*	t	4.5	7.3	2.26	5.9	1.5	0.42	45.7	17.6	5.55	silt loam

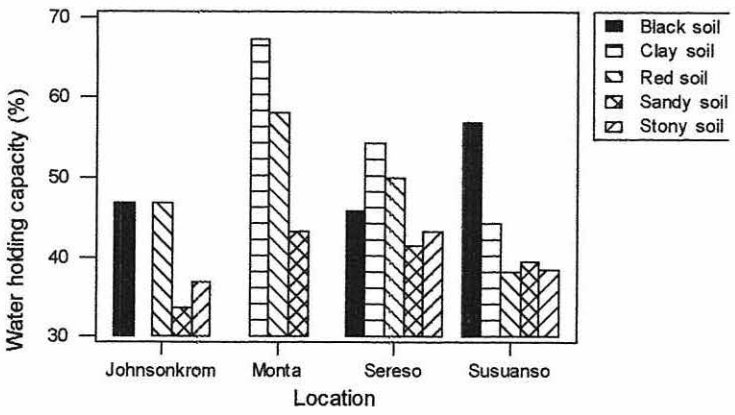
Table V O Analysis of soils from Susuanso

Soil type			Available N (mg kg^{-1})			P (mg kg^{-1})			K (mg kg^{-1})			pH			EC (µS cm^{-1})		
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.
Stony soil	*Abosia*	s	1.9	1.6	0.48	2.3	0.6	0.18	0.0	0.0	0.00	6.46	0.43	0.12	18	6	1.86
Stony soil	*Abosia*	t	8.7	10.9	3.42	2.7	2.2	0.65	26.9	12.6	3.98	6.67	0.08	0.03	47	19	5.51
Sandy soil	*Afonwea*	s	17.6	25.6	7.46	2.7	2.2	0.67	12.5	16.4	5.33	6.22	0.43	0.13	122	68	19.70
Sandy soil	*Afonwea*	t	18.6	21.7	6.35	5.5	2.0	0.57	33.0	10.4	5.18	6.45	0.43	0.13	127	102	30.51
Clay soil	*Afroo*	s	1.8	0.1	0.05	2.2	1.3	0.37	36.3	108.8	36.25	6.79	0.51	0.15	33	8	2.40
Clay soil	*Afroo*	t	7.0	4.8	1.38	6.1	1.5	0.45	35.1	34.4	10.08	6.58	0.33	0.10	74	19	5.69
Red soil	*Asase kokoo*	s	3.2	3.6	1.09	2.6	3.0	0.87	0.5	1.6	0.52	5.72	0.92	0.28	33	8	2.31
Red soil	*Asase kokoo*	t	12.7	12.6	4.10	3.4	2.5	0.71	105.6	108.3	31.26	6.44	0.50	0.17	84	27	8.54
Black soil	*Asase tuntum*	s	4.9	3.1	0.94	2.2	1.3	0.36	0.0	0.0	0.00	5.77	0.88	0.26	70	92	28.50
Black soil	*Asase tuntum*	t	19.7	10.6	3.09	3.8	3.3	0.96	51.0	49.5	15.84	6.42	0.23	0.07	128	107	32.04

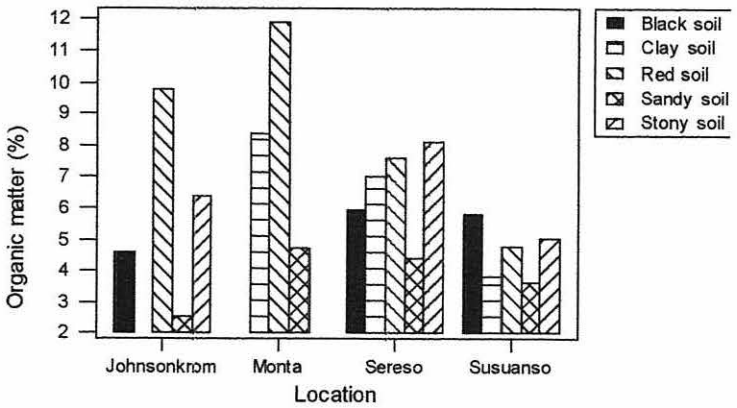
Table V P Analysis of soils from Susuanso

Soil type			gravel (%)			Organic matter (%)			Water holding capacity (%)			Texture
			Mean	Range	s.e.	Mean	Range	s.e.	Mean	Range	s.e.	
Stony soil	*Abosia*	s	23.1	18.4	5.63	4.2	0.9	0.43	25.1	6.9	2.08	grit
Stony soil	*Abosia*	t	9.7	26.7	8.61	5.0	1.2	0.38	38.4	16.3	5.33	silt loam with grit
Sandy soil	*Afonwea*	s	0.2	0.4	0.12	2.4	0.2	0.05	33.2	3.4	1.00	sandy loam
Sandy soil	*Afonwea*	t	0.0	0.0	0.00	3.6	0.9	0.27	39.3	5.9	1.84	sandy loam
Clay soil	*Afroo*	s	2.8	7.7	2.48	2.4	1.4	0.44	37.5	19.2	6.13	sandy clay loam
Clay soil	*Afroo*	t	0.1	0.1	0.04	3.8	0.2	0.07	44.3	7.8	2.25	sandy silt loam
Red soil	*Asase kokoo*	s	23.3	3.1	1.00	3.7	1.3	0.40	34.4	4.2	1.31	sandy to clay silt loam
Red soil	*Asase kokoo*	t	0.7	1.6	0.49	4.8	1.1	0.34	38.1	1.5	0.47	sandy to clay loam
Black soil	*Asase tuntum*	s	1.1	1.4	0.46	3.3	2.6	0.77	47.2	7.0	2.14	sandy silt loam
Black soil	*Asase tuntum*	t	0.2	0.3	0.10	5.8	1.5	0.49	56.9	8.5	2.52	silt loam

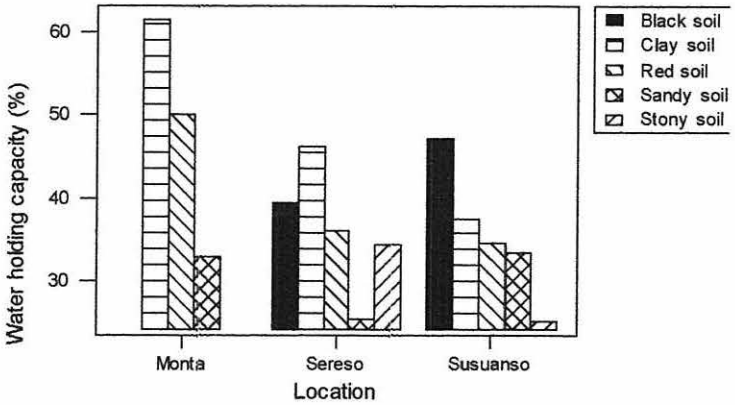
Mean water holding capacity of 0 - 15 cm soil layer



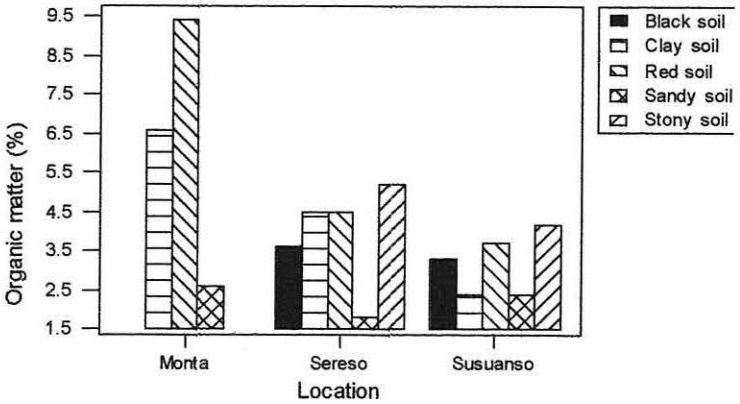
Mean organic matter in 0 - 15 cm soil layer



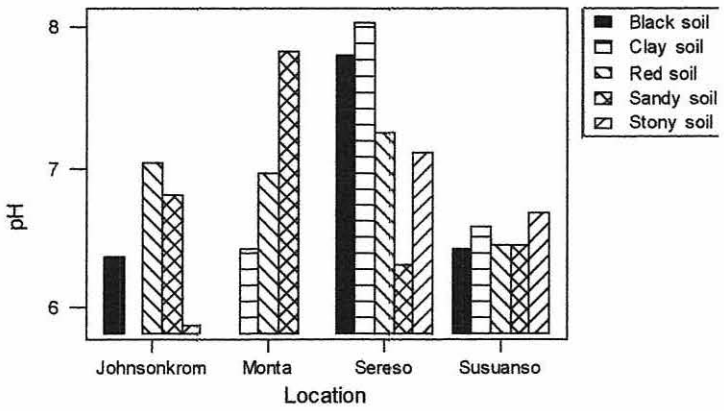
Mean water holding capacity of 15 - 30 cm soil layer



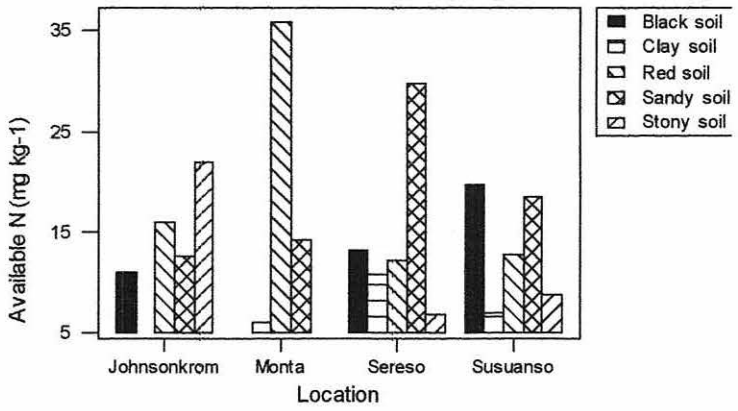
Mean organic matter in 15 - 30 cm soil layer



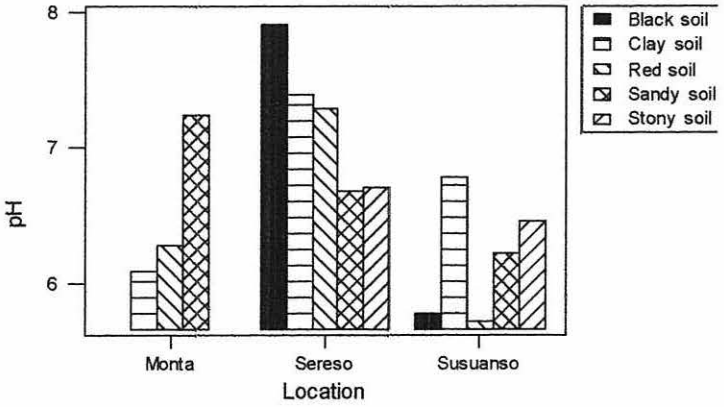
Mean pH of 0 - 15 cm soil layer



Mean available nitrogen in 0 - 15 cm soil layer



Mean pH of 15 - 30 cm soil layer



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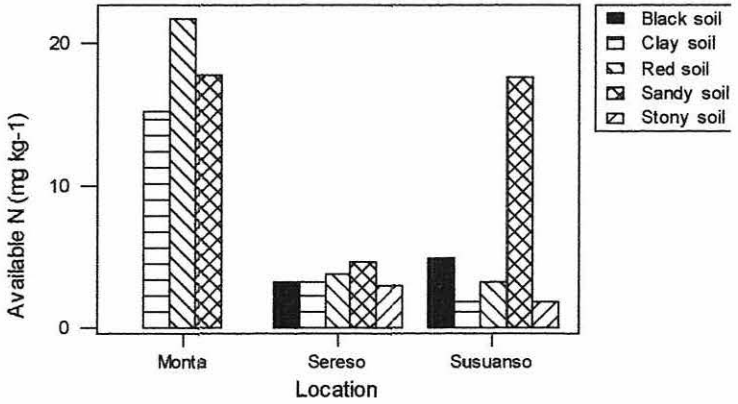
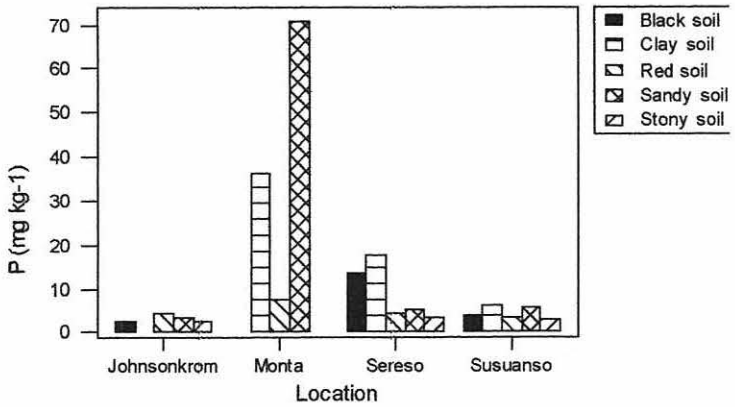
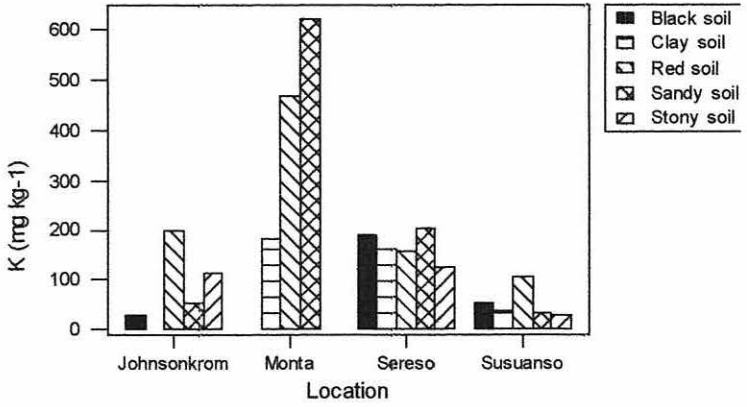


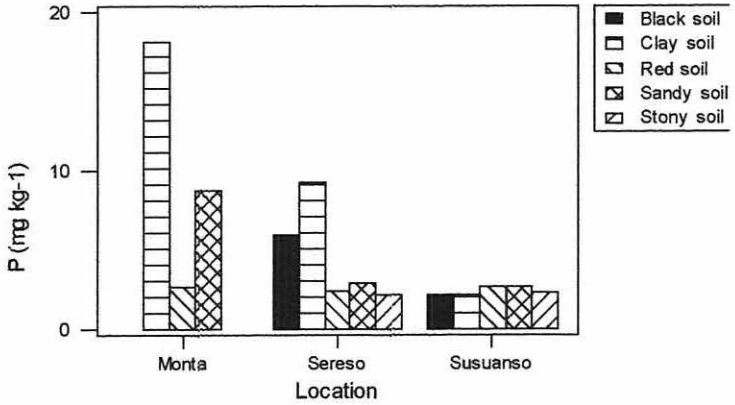
Mean P in 0 - 15 cm soil layer



Mean K in 0 - 15 cm soil layer



Mean P in 15 - 30 cm soil layer



Mean K in 15 - 30 cm soil layer